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Current Trends in Audiological Practices and Implications for Developing Countries

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Abstract

This paper examines the current trends in audiological practices in Nigeria, as it makes case for compulsory use of electro- physiological tests in determining the hearing potentials of children in the country, as against the use of behavioural audiometric strategy which requires the active participation of the patients. Varieties of electro-physiological tests such as Auditory Brainstem Response Test (ABR), Oto- Acoustic Emission, and modern advances such as cochlear implants and auditory brainstem implants for Neuro- Fibromatosis type 2 (NF2) as practiced in developed countries were explained. These current trends in audiological practices should serve as a catalyst to stimulate the developing countries in managing hearing and speech disorders.

Keywords: Audiological practices, Developing countries, Audiological investigations, Audiological Management

1. Introduction

During the dark ages, hearing tests consisted of dropping a coin on the floor behind a person to determine his hearing ability. Funnel-shaped ear trumpets were used as hearing aids. It was not until after World War II that audiology became a formal field of study, with major universities forming audiology departments and offering undergraduate and graduate programs. Many injured veterans returning to the US had hearing losses or difficulty interpreting what they were able to hear. In order to help these veterans, medical professionals began serious research on how the ear functions and how information is processed neurologically (central auditory processing – CAP). The focus for the next several decades was on the development of more scientific and precise diagnostic tests. Computer technology greatly advanced diagnostic sophistication and has even provided, recently, the ability to diagnose sensory from neural hearing loss. Computers even lead to the discovery of an entire new area of auditory disturbance – auditory neuropathies. New technology also enabled the development of CAP tests designed specifically for children (NJSHA, 2011).

After World War II, new, yet still crude, amplification devices were developed. One of the first hearing aid units was a set of earphones connected to a large case with heavy batteries. Next was the transistor-radio styled device that fit into a pocket and had a wired earpiece (body worn hearing aid). This was followed by the behind-the-ear hearing aids. Hearing aid devices functioned on analog circuitry, amplifying sounds that were closest to the aid's microphone. Analog technology offered some benefit, but could not regulate sounds well in noisy places like restaurants. Today, we have digital hearing aids that provide better sound quality and user satisfaction. Digital circuits specifically identify speech sounds while reducing background noise, which provides improved word intelligibility in all listening environments (NJSHA, 2013).

Perhaps the most revolutionary development has been the Cochlear Implant, a hearing device surgically implanted into the ear. Originally designed for adults with sudden lost hearing, the implant has been especially successful with children because of the young brain's ability to adapt to the technology. The Cochlear Implant has the potential to beat deafness. Children as young as six months can be fitted, which will enable them to develop speech, language and learning the same as children born with normal hearing. To better diagnose and treat hearing problems earlier, some developed countries of the world had mandated hearing screening for all newborns before hospital discharge or within their first 30 days, receiving diagnostic audiological evaluation by three months of age and enrolling in early intervention services by six months of age if needed. This is known as 1 – 3 – 6 goal. It is pivotal for hearing problems to be diagnosed and treated early so that children can learn language and social skills that will enable them to communicate effectively.

The current trends in audiological practices will be discussed in two dimensions: investigations and management.

2. Audiological Investigations

2.1 Pure Tone Audiometry

It will be highly rewarding to begin current trends in audiological practices by briefly discussing a conventional method used in measuring hearing sensitivity across a range of frequencies known as pure tone audiometry (PTA). Pure-tone sensitivity can be measured by air conduction and bone conduction testing. The audiogram is a graph showing the hearing sensitivity for air and bone conducted sounds. The frequency at the tone in Hertz (Hz) is represented along the abscissa, and hearing level in decibels (dB) along the ordinate. The frequencies used in clinical measurement include only those from 250 Hz to 8000 Hz even though young normal adults can hear frequencies as low as 20 Hz to as high as 20,000 Hz (Miller, Groher, Yorkston & Rees, 1993). The audiometer is an electronic device for measuring hearing ability (or absence of it) which produces pure tones. The intensity of these tones or frequencies can be adjusted according to the threshold of sound perception of the patient. In its simplest form, it is a pure-tone oscillator, an amplifier, and an attenuator. A selection of different frequencies can be obtained by altering the output from the pure-tone oscillator through manipulation of the frequency selector switch and the tone can be turned on and off by pressing or releasing the stimulus button. The intensity dial controls the intensity of the stimulus. A noise generator is usually included to provide masking when needed. All diagnostic audiometers are equipped with a set of earphones and a bone vibrator so that both air and bone-conduction tests could be performed.

The symbols used on the audiogram are not completely standardized; however, the air-conduction threshold for the right ear is usually represented by a red “O” and the air-conduction threshold for the left ear by a blue “X”. Even less agreed upon are the symbols for bone conduction and masking. However, the symbol < is frequently used for bone conduction in the right ear in red ink and > for bone conduction in the left ear. When masking is done, the amount of masking should be indicated in a corner on the audiogram with other keys to all the symbols used.

Pure Tone Audiometric Testing

The first thing to do in pure-tone testing is to take a case history after which otoscopic examination is important to know the condition of middle ear. Then, the audiologist should take the patient into the sound proof booth; he will tell him that he wants to perform a hearing test. The audiologist will instruct his patient that he will be listening to some sounds (pure tones) and at any period he hears the sound whether soft or loud, he should respond by depressing the patient response button given to him. He can give him an example of the sound that he would hear, inasmuch as he avoids high decibels in order not to traumatize his tympanic membrane and he should also ask him if one ear is better than the other, if so, he is to begin the test from the better ear. The red ear phone is to be fitted on the right ear while the blue goes to the left ear) and he begins to test on 1000 Hz at 0 dB. He will ascend by 5 dB and descend by 10 dB; this is called tracking the threshold. He must press the button on a frequency three times and if the patient responds twice out of these three, he has passed the test and that is his threshold for that frequency. If he responds only once out of three, he has failed the test on that particular decibel at that frequency and the audiologist is supposed to increase the decibel by 5 dB until the patient responds twice and that will be his threshold for that frequency.

Having done with 1000 Hz, he proceeds to 2000 Hz and continues on that last threshold on 1000 Hz, for example, if the threshold recorded for 1000 Hz was 40 dB, he starts testing 2000 Hz on 40 dB, if he hears at 40 dB, he must go down to 30 dB, if at 30 dB, the patient does not hear then he moves up to 35 dB. If he hears at 35 dB, the audiologist confirms that he actually hears before he records it as his threshold for 2000 Hz. Then he moves to 4000 Hz, and to 8000 Hz. Moreover, he goes back to 1000 Hz for test-retest to validate his result. It should be noted here that if two different results were obtained on 1000 Hz when test retest is being conducted, the first result should be marked with “$O^{1"}$ or “$X^{1"}$ and the second with “$O^{2"}$ or “$X^{2"}$ depending on the ear he is testing and choose the more valid result out of the two. After this, he goes to 500 Hz and follows the normal testing process until he gets to 125 Hz and the same is done for the other ear. This is the same procedure for bone conduction testing, only that the ear phone is changed to bone vibrator which will be placed on the mastoid bone, unlike the ear phone that is placed on the external ear. Moreover, only four frequencies are usually tested for bone conduction testing; 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz, unlike air conduction testing that involves eight frequencies.

Charting / Configuring the Audiogram

Mark with a red "O" on the right and with a blue "X" on the left for air conduction thresholds. For bone conduction thresholds, mark right ear with an arrow facing left "<" in red ink while the left ear is marked blue with an arrow facing right ">". Also, the symbols are joined together with continuous line in air conduction testing while broken lines are used for bone conduction testing.

Interpretation of Test Results

A pure tone average is derived by the average of the summation of the three speech frequencies (500 Hz, 1000 Hz and 2000 Hz) for each ear. This pure tone average is referred to as the threshold of each ear. A person has normal hearing when his threshold is less than or equal to 25 dB. However, this degree of hearing varies among states and countries of the world. A conductive hearing loss is when a patient's bone conduction testing falls below 25 dB while his air conduction testing is above 25 dB. A sensorineural hearing loss is defined with an audiogram having both air and bone conduction testing above 25 dB but without air-bone gap (that is, the gap should not be up to 10 dB). A mixed hearing loss audiogram also has both air and bone conduction testing above 25 dB but with a-b gap (here, the gap is more than 10 dB).

2.2 Tympanometry

Tympanometry is an examination used to test the condition of the middle ear (Steele, Susman & Mccurdy 2003). It also tests the mobility of the eardrum (tympanic membrane) and the conduction bones by creating variations of air pressure in the ear canal. Tympanometry is an objective test of middle-ear function. It is not a hearing test, but rather a measure of energy transmission through the middle ear. The test should not be used to assess the sensitivity of hearing and the results of this test should always be viewed in conjunction with pure tone audiometry.

A tympanogram is a graphic representation of the relationship of external auditory canal air pressure to impedance. This can be classified into three basic types on the basis of the configuration of the tympanogram.

Type A – The peak compliance occurs at or near atmospheric pressure indicating a normal pressure in the middle ear. There are three sub-groups:

A – normal shape that reflects a normal mechanism.

A_d - A deep curve with a tall peak which indicates an abnormally compliant middle ear, as seen in ossicular dislocation or erosion or loss of elastic fibres in the tympanic membrane.

As – A shallow curve indicating a stiff system as seen in otosclerosis.

Type B – No sharp peak, with little or no variation in impedance over a wide range usually secondary to non-compressible fluid in the middle ear (otitis media), tympanic membrane perforation or obstructing cerumen.

Type C – Peak compliance is significantly below zero, indicating negative pressure (sub-atmospheric) in the middle ear space. This finding is often indicative of Eustachian tube dysfunction.

2.3 Otoacoustic Emissions

Otoacoustic emissions, (OAEs), are tiny sounds generated by movement of outer hair cells of a normal inner ear following auditory stimulus. These sounds are recordable by inserting a probe with a soft flexible tip in the ear canal to obtain a seal. Different probes are used for different people depending on the age and size of ear canal. OAEs are absent when there is a mild or greater sensorineural hearing loss (more than 30dB), and absent when there is middle ear fluid. When testing is complete, there will be a display on the liquid-crystal display (LCD), 'PASS' on the screen indicates the patient passed the screening, 'REFER' indicates that the patient did not pass the screening. The elements in the pathway for the OAE include the sound source, the ear drum, ossicular chain, inner ear, and outer hair cells. The same structures transmit sound coming out of the outer hair cells. OAEs can be affected by anything in the chain. If sound does not get in or out, there will be no OAE. If there is a resonance or filter between the sound source and microphone, this will cause altered frequency spectrum of OAEs (Grenner, 2012).

Usefulness of OAE

The clinical significance of OAE's is that they only occur in a normal cochlea with normal or near normal hearing. If there is damage to the outer hair cells producing mild hearing loss, then OAEs are not evoked. A rule of thumb is that OAEs are present if hearing is 35 dB or better. Because OAEs are evoked by transient signals that have a wide frequency response, a broad region of the cochlea responds, providing information on the frequency range from 1000 Hz to 4000 Hz. OAE's decline with age.(Cilento, Norton & Gates 2003). The clinical experience with OAE's, is that they do not discriminate well between causes of hearing loss. In other words, someone with an intact cochlea (including their outer hair cells), perhaps due to an acoustic tumor, is to be equally likely to have absent OAE's as someone with cochlear damage due to noise. Kagova, Shinogami, Kohno & Yamasoba (2012) have observed that OAE's are generally reduced by acoustic neuromas. OAE's are appropriate for use in difficult-to-test patients: newborn infants, young children, patients who are attempting to feign a hearing loss (i.e. malingering), and developmentally delayed populations. OAEs primarily provide information about the activity of the cochlea, and do not assess the status of the rest of the auditory pathway, except for crossed responses mediated through the cochlear efferent system. OAE's have a special utility in auditory neuropathy. This is a condition, primarily of children, in which hearing is impaired but cochlear function is presumed intact. This is rather rare. Also, it could be used in cisplatin ototoxicity. Cisplatin is the most widely used anticancer drug currently and unfortunately, it is cochleotoxic. The toxicity begins in the outer hair cells (Reavis er al., 2011), and affects high frequencies first, the same area as age and noise.

2.4 Auditory Brainstem Response

The auditory brainstem response (ABR) is an auditory evoked potential extracted from ongoing electrical activity in the brain and recorded via electrodes placed on the scalp. The resulting recording is a series of vertex positive waves of which I through V are evaluated. These waves, labeled with roman numerals in *Jewett* and *Williston* convention, occur in the first 10 milliseconds after onset of an auditory stimulus. ABR is considered an *exogenous response* because it is dependent upon external factors (Hall 2007). ABR is used in newborn hearing screening, auditory threshold estimation, intra-operative monitoring, hearing loss degree and type, and auditory nerve and brainstem lesion detection.

According to DeBonis & Donohue (2007); Hall (2007), the auditory structures that generate the auditory brainstem response are believed to be as follows:

- *Wave I* – generated by the peripheral portion of cranial nerve VIII
- *Wave II* – generated by the central portion of cranial nerve VIII
- *Wave III* – generated by the cochlear nucleus
- *Wave IV* – generated by the superior olivary complex/lateral lemniscus
- *Wave V* – generated by the lateral lemniscus/inferior colliculus

ABR Testing Procedures

The patient should be made as comfortable and relaxed as possible to minimize any potential muscle artifacts and ensure optimum test outcome in the shortest time. The face, neck and shoulder of the patient are also to be relaxed. Electrodes are placed on three locations on the patient's head i.e. the centre of the forehead at the hairline, the side of the forehead near the temple or on the cheek and the nape of the neck or the right mastoid. The skin should be cleaned with an electrode skin preparation product to remove any oil or dirt from the skin surface before the placement of the electrodes. Then begin the test by clicking 'start measurement' button. In normal hearing population, the auditory wave V (inferior colliculus) will be clearly defined but for those with hearing loss, it will be absent or less defined with much longer latencies.This is because the inferior colliculus is essential for hearing, connecting the auditory brain stem to sensory, motor, and limbic systems, the inferior colliculus is a critical midbrain station for auditory processing (Winer & Schreiner 2005).

3.Audiological Management of Hearing Loss

3.1 Hearing Aids

A hearing aid is an electroacoustic device which typically fits in or behind the wearer's ear, and is designed to

amplify and modulate sound for the wearer. Earlier devices, known as ear trumpets or ear horns were passive funnel-like amplification cones designed to gather sound energy and direct it into the ear canal. Similar devices include the bone anchored hearing aid, and cochlear implant (Bentler, Duve & Monica, 2000).

3.2 Cochlear Implants

In 1980, the first child in the world was implanted with the single-channel House cochlear implant device (Eisenberg & House, 1982). Children who initially received cochlear implants during this first paediatric clinical trial were quite old compared to current ages (the average age in the first House clinical trial was 8 years, whereas children are now being implanted as young as 6 months of age), and the majority communicated using sign language (Eisenberg & Johnson, 2008). It is now known that implanting older children who do not communicate orally gives little chance of speech perception or spoken language development. A cochlear implant is a small electronic device consisting of surgically implanted internal components with an externally worn speech processor. An implant has four basic components, these are microphone, speech processors, transmitter and receiver/stimulator and electrodes (ASHA, 2011).

Cochlear Implant Candidacy

- Severe to profound sensorineural hearing loss in both ears.
- Functioning auditory nerve
- Bilateral hearing loss
- No benefit from other kinds of hearing aids, including latest models of high power hearing instruments and FM systems
- Have no medical contraindications to surgery

Approximately 2–4 weeks after surgery, the patient returns to the clinic for fitting of the external equipment. The electrodes are stimulated to determine the level when sound is fist heard and to determine the level when sounds are loud but comfortable. This is a process called “mapping” or “programming” of the implant. Special techniques are used to obtain this information from young children. Patients then return for further fine-tuning of the device on several occasions during the first year of device use. After the first 12 months, annual follow-up is recommended to check the speech processor and to evaluate progress with the device (ASHA, 2011).

3.3 Auditory Brainstem Implant

An auditory brainstem implant provides a sensation of hearing to some people who are deaf due to auditory nerve damage. An auditory brainstem implant is most commonly offered to adults diagnosed with neurofibromatosis type 2 (NF2). This rare genetic condition causes tumors to grow on nerves. When the auditory nerves are involved, hearing can be destroyed. Sensors in the auditory brainstem implant bypass the damaged auditory nerves and connect directly to the brainstem to help people detect sounds. Although cochlear implants (CIs) are highly successful at restoring functional hearing, some people have no remaining auditory nerve and cannot benefit from a CI. These patients have lost their auditory nerve (VIIIn) from a variety of causes, most commonly neurofibromatosis type 2 (NF2). NF2, a genetic defect on chromosome 22, causes tumors originating in the Schwann cells that insulate the auditory nerve where it exits the internal auditory meatus. When the tumors are removed the auditory nerve is usually cut and no connection exists between the still-functioning cochlea and the brain. Other causes of VIII nerve loss are temporal bone fracture, congenital aplasia of the cochlea and/or nerve, and severe ossification from congenital or post-meningitic growth (Shannon, 2011).

The auditory brainstem implant (ABI) is similar in design and function to a CI, except that the electrode is placed on the first auditory relay station in the brainstem, the cochlear nucleus (CN). The ABI electrode array is a small (8 x 3 mm) paddle that contains 21 small electrode contacts. Unlike the cochlea, which has a single linear tonotopic organization from base to apex, the CN has several tonotopic maps that are at different angles to one another within the nucleus. The CN also has multiple cell types that are specialized to extract different types of information from the VIII nerve input. The ABI electrode array is placed along the surface of the CN and each electrode likely activates a variety of neuron types, possibly with different characteristic frequencies (Shannon, 2011).

Auditory Performance

NF2 patients with an ABI receive sound sensation on most electrodes that produce distinct pitch sensations (Otto, Brackmann, Hitselberger, Shannon & Kuchta, 2002). Electrodes that produce only non-auditory sensations (mostly tingling sensations along the ipsilateral side of the body) are turned off and not included in the implant program. Patients with the ABI can detect and discriminate sounds based on their temporal and amplitude properties. This auditory information improves their face-to-face communication by about 30 percentage points by supplementing speech reading. However, most NF2 ABI recipients cannot identify words or sentences with only the sound from the ABI—a few patients have more than 20% word understanding. When ABIs are provided to patients who have lost their auditory nerve from causes other than NF2 (non-tumor or NT patients), the outcomes of the ABI are dramatically different. Colletti and colleague in Verona, Italy, have demonstrated that about 50% of NT ABI patients have sentence understanding of more than 50% with only the sound from the ABI without speech reading (Colletti & Shannon, 2005).

Several of these patients achieved speech understanding equivalent to the best performance of CI patients. These results demonstrate that electrical stimulation of the human brainstem (CN) can provide excellent speech understanding for some patients. It also suggests that the cause of poor speech recognition in NF2 ABI patients may be related to NF2. However, recent results in Europe have demonstrated speech recognition levels similar to those of CI patients in NF2 ABI patients, a level previously not obtained by hundreds of patients with ABIs around the world (Behr, Muller, Shehata-Dieler, Schlake., Helms & Roosen, 2007).

4. Conclusion

One of the key developments in audiological practices in the last twenty years around the world is the introduction of universal newborn hearing screening systems. These programs are proliferating all over the developed world, but are infants in the developing countries today. Other important advancement are seen in the management of people with hearing loss, these include high technology assistive listening devices and hearing aids, cochlear implants and auditory brainstem response. Of course, one of the most significant advances of the last twenty years is the growth, expansion and recognition of the profession of Audiology all over the world. In Nigeria, there has been a significant recognition of Audiology as a profession more than before, not only in the public sector but also in the private sector, this is positively affecting the management of speech and hearing defectives.

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