COMPARING THE HEARING THRESHOLDS BETWEEN MASTER (MULTIPLE AUDITORY STEADY-STATE RESPONSE) AND PTA (PURE TONE AUDIOMETRY) IN NORMAL HEARING AND IMPAIRED HEARING INDIVIDUALS

By

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LIST OF ABBREVIATIONS

ABR	-	Auditory Brainstem Response
AEP	-	Auditory evoked potential
ASSR	-	Auditory Steady-State Response
BHI	-	Better Hearing Institute
CDC	-	Centre for Disease Control
dB	-	Decibel
dB HL	-	Decibel of Hearing Level
HUKM	-	Hospital Universiti Kebangsaan Malaysia
HUSM	-	Hospital Universiti Sains Malaysia
JCIH	-	Joint Committee on Infant Hearing
kHz	-	Kilohertz
MASTER	-	Multiple Auditory Steady-State Response
OAE	-	Otoacoustic Emission
PTA	-	Pure Tone Audiometry
SD	-	Standard Deviation
UNHS	-	Universal Neonatal Hearing Screening

ABSTRAK

PENGENALAN

Masalah pendengaran di kalangan kanak-kanak perlu dikenalpasti awal dan dengan tepat. Ini penting bagi melaksanakan proses intervensi dan rehabilitasi. 'Auditory Steady-State Response (ASSR)' telah dibuktikan sebagai satu kaedah audiometri yang objektif dan frekuensi spesifik dan dapat memastikan keputusan tahap pendengaran dalam lingkungan 5 hingga 20 dB daripada keputusan 'Pure Tone Audiometry' (PTA). Memandangkan keputusannya tidak dipengaruhi oleh umur, adalah wajar untuk menggunakan ASSR bagi menilai tahap pendengaran di kalangan kanak-kanak.

OBJEKTIF

Tujuan kajian ini adalah untuk mendapatkan data yang normal bagi populasi. Juga membuat perbandingan tahap pendengaran yang didapati melalui kaedah PTA dan MASTER bagi menentukan ketepatan MASTER dalam meramalkan tahap pendengaran bagi kumpulan yang mempunyai pendengaran yang normal dan pendengaran yang tidak normal.

METODOLOGI

Satu kajian hirisan-lintang telah dijalankan di unit audiologi, HUSM dari bulan Januari hingga Julai 2007. Seramai empat puluh orang subjek dewasa dan tiga puluh empat orang subjek kanak-kanak terlibat di dalam kajian ini. Setiap seorang daripada mereka dibahagikan lagi kepada kumpulan yang mempunyai pendengaran yang normal dan pendengaran yang tidak normal. Kemudian setiap subjek akan melalui PTA dan MASTER.

KEPUTUSAN

Perbezaan di dalam purata tahap pendengaran di antara PTA dan MASTER adalah 18 dB HL (SD=8.5) bagi subjek dewasa yang mempunyai pendengaran normal dan 14 dB HL (SD=6) bagi subjek kanak-kanak yang mempunyai pendengaran normal. Namun nilai-

nilai ini adalah lebih kecil di dalam kumpulan yang mempunyai pendengaran yang tidak normal. Perbezaan di dalam purata tahap pendengaran adalah 13 dB HL (SD=8.5) bagi subjek dewasa dan 11 dB HL (SD=6) bagi subjek kanak-kanak. PTA dan MASTER mempunyai hubung-kait yang sangat tinggi (r=0.73) dan bila analisis dibuat berdasarkan frekuensi didapati bahawa 'correlation coefficient' adalah 0.57, 0.52, 0.77 dan 0.70 untuk frekuensi 0.5, 1.0, 2.0 and 4.0 kHz.

KESIMPULAN

Kajian ini telah membuktikan bahawa MASTER boleh meramalkan keputusan PTA dengan tepat dalam kumpulan yang mempunyai pendengaran yang normal dan pendengaran yang tidak normal.

ABSTRACT

INTRODUCTION

Hearing impairment in adults and children need to be identified early and accurately. This is important for the proper implementation of intervention and rehabilitation. The Auditory Steady-State Response (ASSR) has been established as a frequency-specific, objective audiometric procedure, which can provide reliable thresholds to within 5-20 dB of the pure tone behavioural thresholds. And since, its measurements are not influenced by age, it is appropriate to use ASSR for the hearing assessment in children.

OBJECTIVE

The aim of the study is to obtain the norms for the population and to compare hearing thresholds obtained by Pure Tone Audiometry (PTA) and by Multiple Auditory Steady-State Response (MASTER) in order to determine the accuracy of MASTER in estimating hearing thresholds for normal hearing and hearing-impaired individuals.

METHODOLOGY

A cross-sectional study was conducted in the Audiology Unit, Department of Otorhinolaryngology, HUSM from January to July 2007. A total of forty adults and thirty-four children were involved in the study. They are further divided into normal hearing and hearing-impaired groups. Each subject underwent PTA and MASTER on the same day.

RESULTS

The mean threshold difference between PTA and MASTER was 18 dB HL (standard deviation= 8.5) in normal hearing adults and 14 dB HL (SD=6) in normal hearing children. However these values were smaller in the hearing-impaired subjects. The mean threshold difference was 13 dB HL (SD=8.5) in adults and 11 dB HL (SD=6) in children. The PTA and MASTER were highly correlated (r=0.73) and when analysed according to the frequencies, the correlation coefficients of 0.57, 0.52, 0.77 and 0.70 for 0.5, 1.0, 2.0 and 4.0 kHz, respectively, shows good correlation.

CONCLUSION

This study confirmed that MASTER is an accurate predictor of the PTA thresholds in normal hearing and hearing-impaired subjects.

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

Hearing loss is the impairment in the ability to apprehend sound in one or both ears. World Health Organisation,WHO defined hearing impairment as hearing loss greater than 25 dB.

Hearing impairment is an important health issue, both in adult and in children. It has a devastating effect especially in children because without normal hearing in the first few years of life, speech and language development do not develop as rapid or as completely as normal. Even in adult this impairment can lead to embarrassment, handicap, job losses and loss of satisfaction in social activities.

1.1. Prevalence of Hearing Impairment

In Europe, it is estimated one in six adults suffers from hearing loss and only a fraction of those with hearing impairment actually use hearing aids (Evaluation of the Social and Economic Costs of Hearing Impairment, October 2006). A survey conducted by BHI (Better Hearing Institute) in July 2005, showed an increase of 9.9 % of Americans have hearing impairment since 2000 but only 1 out of 4 of them use hearing aid.

A Malaysian Burden of Disease and Injury Study were conducted in 2000. The non-fatal health outcomes such as mental disorders, musculoskeletal disorders and sense organ disorders become apparent as large health problems in the Malaysian population. This study revealed that the number one cause of Years Lived with Disability (YLD) in Malaysian male is hearing loss accounting for 7.7 %. While in female, it accounts for 7.4% which come second after unipolar major depression (Malaysian Burden of Disease and Injury Study Forum Presentation, 2005). In other words, loss of healthy life due to hearing loss creates a major burden, not only in health but as a consequence, in economy and social issues too.

The prevalence of mild to profound hearing loss is reported to be between 1.1 and 6 per 1,000 life-births (Better Hearing Institute (BHI) "MarkeTrak VII" Survey, 2005). Survey by CDC (Centre for Disease Control) estimated that two percent of all children are born with hearing loss in USA. The figures for European children are estimated to be at the same level (Better Hearing Institute (BHI) "MarkeTrak VII" Survey, 2005). A local study by Abdullah A. and colleagues (2006), determined the prevalence of around 0.42 % of neonates with hearing loss identified by the hearing screening programme carried out in Hospital Universiti Kebangsaan Malaysia (HUKM). However this value is quite low compared to other studies, most probably due to the high defaulter rate in the study and they only managed to cover 89.2 % of the newborn. The recommendation by the Joint Committee on Infant Hearing 2000 is > 95 %. The prevalence among high-risk infants is between 2.5% and 10%. Khairi et.al. in 2005 reported a total of 1% of hearing loss detected in the screening of high risk neonates in Hospital Universiti Sains Malaysia (HUSM).

Hearing impairment in infants should be identified as early as possible to enable intervention to take full advantage of the plasticity of the developing sensory system. A study of young children with hearing loss, Yoshinaga-Itano (1995) found that if children are identified by six months of age, they had significantly higher developmental functioning in general development, expressive and receptive language and personal-social areas.

Initially, the neonatal hearing screening programme only involved the high-risk infants. However, they only comprise 50% of infants with hearing impairment. Therefore, the other 50% of infants with hearing impairment but has no risk factors is not identified. Hence, universal neonatal hearing screening has been recommended. In the Joint Committee on Infant Hearing (JCIH) 1994 Position Statement, universal detection of infants with hearing impairment is recommended before the age of three month (Luts & Wouters, 2004).

1.2. Assessment of Hearing

Accurate and reliable diagnostic information need to be obtained as it forms the basis of early intervention. It is important, in some cases to obtain frequency-specific threshold, for example in cases of congenital hearing loss with frequency-dependent where this information is essential for proper management with hearing aids or cochlear implant (Canale et.al., 2006). Accurate amplification of hearing aids or implants can only be provided if accurate, ear specific information on the type, degree and configuration of a hearing loss is available (Yoshinaga-Itano, 2001). This can only be provided by the Pure Tone Audiometry (PTA) which is considered the gold standard of frequency-specific threshold audiometry. However, PTA relies on behavioural responses and this preclude its usage in the "difficult to test" population (Stach, 1998). Neonates, difficult to test children, the mentally, physically or multiply handicapped, as well as those suspected of non-organic hearing loss, are classified in this population due to factors such as lack of attention, motivation and understanding of instructions (Picton, 1998).

The existing framework of objective assessments is primarily the use of OAE (otoacoustic emission) and ABR (auditory brainstem evoked response). These two techniques provide complimentary information. Certain types of OAE can provide frequency specific information but OAE is unable to evaluate the neural auditory pathways and subsequently is not a threshold-seeking procedure (Hall, 2000). Only ABR can estimate the physiological auditory thresholds. Similar to other types of auditory-evoked potentials (AEP) procedures, it employs measuring the electrophysiological changes in the brain which are evoked by acoustic stimuli. Presently, ABR is the most widely used AEP technique to assess hearing in young children (Swanepoel et.al., 2004).

ABR evoked by click stimuli is the most utilized in clinical setting due to its high reproducibility and stability of waveform (Canale et.al., 2006). However, its main limitation is that it cannot provide frequency specific thresholds because the click stimuli elicit a broad spectral splatter. At best, the degree of frequency specificity of the responses is described as correlating moderately with the behavioural thresholds in the 1-4 kHz region (Canale et.al., 2006, Reijiden et.al., 2001).

A further refinement of the click-evoked ABR is the tone-burst ABR. The tone-burst ABR is able to mask the spectral splatter and provide frequency specificity and thus can accurately estimate the behavioural thresholds. However, this technique has not been introduced in the clinical setting because it has been described as time-consuming, and technologically complex and requiring expertise to interpret the results, in other words, without an automated response detection (Picton et.al., 1998, Perez-Abalo et.al., 2001, Ahn et.al., 2007).

Because of these limitations, new techniques have been developed and one that is rapidly gaining popularity is the Auditory Steady-State Response (ASSR).

1.3. Auditory Steady-State Response (ASSR).

The objective of the Auditory Steady-State Responses procedure is to obtain frequcncy specific thresholds from "difficult-to-test" subjects without any responses required.

Historically, ASSR evolved from experiments done in early 1980s by Galambos and colleagues (Aoyagi et.al., 1996). Stimuli were presented at a rate of 40 Hz and to only one ear at each time. It forms the basis for further researches. Mainly ASSR was developed for threshold estimation in young children but the major application has been for assessing the cochlear implant candidates (Aoyagi et.al., 1996).

The ASSR stimulus has many characteristics which made it applicable to the hearing assessment.

1.3.1. Modulation of Stimuli

ASSR is evoked using sustained continuous acoustic tones/ stimuli, which are modulated in amplitude and/or frequency. Numerous studies have proven that modulation of a tone at a high rate provides valuable information regarding the hearing sensitivity of subjects in a frequency specific manner (Lins et.al., 1996). The ASSR stimuli or tones are modulated in amplitude by adding a frequency in the range of either around 40 Hz or 80 Hz (75-110 Hz) rate of modulation to the carrier frequency (the frequency to be assessed). By combining amplitude and frequency modulation, larger evoked potentials can be recorded thus making the recording of those responses more reliable (Perez-Abalo et.al., 2001).

1.3.2. Rate of Modulation

Unlike other AEP procedures which have transient responses (rate of stimulus allows the response to one stimulus to be recorded before the next stimulus is presented) (John et.al., 1998), ASSR stimuli are presented at high rate of presentation. These cause the overlapping of responses, which evokes the steady-state potentials (Lins et.al., 1996).

Early studies using tones modulated at 40 Hz had shown that these tones were significantly affected by the state of consciousness (Lins et.al., 1996, Perez-Abalo et.al., 2001). Further studies found that higher modulation rates, between 75-110 Hz, are less susceptible to sleep and sedation and more applicable to the "difficult-to-test" population (Lins et.al., 1996).

1.3.3. Monotic and Dichotic Presentation

Another stimulus characteristic of the ASSR is the presentation of the stimuli, which can be presented to either one ear at a time or both ears simultaneously. Monotic single ASSR presents modulated tones to each ear separately in an attempt to obtain frequency specific information (Lins et.al., 1996, Picton et.al., 1998). This is similar to pure tone and ABR threshold procedures. Furthermore, with monotic single ASSR responses can be reliably evoked at high intensities. Thus severe to profound hearing losses can be identified (Picton et.al., 1998). It is also possible to present four different frequencies simultaneously to one ear at a time, referred to as monotic multiple ASSR (Herdman & Stapells, 2001).

The most significant clinical limitation of monotic single ASSR is the time needed to obtain the complete results. Similar to pure tone thresholds, the clinician still need to ascend or descend in intensity to estimate the threshold for each frequency (Perez-Abalo et.al., 2001). Furthermore, it is time consuming because the ears are tested individually and not simultaneously. Due to this limitation, the focus of research is to find a more time-efficient manner of stimulus presentation (Lins et.al., 1996). However, one must remember not to sacrifice accuracy to be time efficient.

The other method of stimuli presentation, is the dichotic ASSR, which refers to presentation of one single tone or a combination of modulated tones to both ears simultaneously (Lins et.al., 1996, Perez-Abalo et.al., 2001). Dichotic multiple ASSR is described as a technique of using multiple amplitude and frequency-modulated tones, presented simultaneously to both ears. This complex acoustic stimuli is capable of simultaneously activating different regions of the cochlea and in so doing estimate four frequency specific thresholds in each ear at the same time (John et.al., 1998, Perez-Abalo et.al., 2001). This technique is applicable provided that distinct modulation rates are used for the different carrier tones so that they are more than one octave apart. In addition, if the carrier frequencies were at least one octave apart, there was no significant decrease in amplitude of the responses in comparison to single stimuli (John et.al., 1998). Since the amplitude of responses was similar, the same responses can be obtained.

The main advantage of the dichotic multiple ASSR is that it allows rapid assessment of the hearing thresholds at multiple frequencies at both ears simultaneously (Picton et.al., 1998). This leads to a significant reduction in recording time (John et.al., 1998, John et.al., 2003, Swanepoel et.al., 2004).

These monotic single and dichotic multiple ASSR have been made available to clinicians in the form of GSI Audera and the MASTER system as part of the Biologic software, respectively (Swanepoel, 2001).

1.4. ASSR vs ABR

Both ASSR and ABR has been established as being reliable and accurate in estimating hearing thresholds (Swanepoel, 2004). When comparison is made, there are certain differences that can be highlighted :

1) Both procedures are unaffected by sleep or sedation making them very useful in the “difficult- to-test” population. However with the ASSR, higher modulation rates of presentation need to be used for it to be resistant to the subjects state of consciousness . (Picton et.al., 1998).

2) The detection of responses is automated in ASSR, therefore no interpretation of responses is required. On the contrary, recorded responses of ABR require interpretation before any conclusion can be made (Swanepoel, 2004).

3) The reproducibility and stability of the ABR responses is high but not for the ASSR responses. Further researches are needed to establish this in ASSR (Picton et.al., 1998).

4) The transient stimuli (click or tone burst) in ABR tend to cause spectral splatter which influences the frequency specificity (Gorga, 1999). In ASSR, the steady state responses is evoked by frequency specific stimuli where the carrier frequency is modulated in amplitude and presented in the specific frequency

modulation rate (John & Picton, 2000). This will activate a limited part of the cochlea, which results in a more frequency-specific response.

5) In ASSR, the stimuli are presented simultaneously at both ears and the recorded responses shows the response to each carrier frequency at its unique modulation frequency at the same time. This technique will decrease the recording time and thus more time efficient.

6) Since the stimuli are continuous with less signal distortion and the responses are stable, ASSR can be used to assess aided thresholds during the evaluation of frequency-specific loss and during the adjustments of hearing aids amplification settings (Picton et.al., 1998, Swanepoel et.al., 2004). In ABR, the transient stimuli will rapidly changes over time, hence it does not show the same advantage as ASSR in assessing aided thresholds (Swanepoel et.al., 2004).

7) ABR is insensitive to thresholds variation within the severe to profound hearing loss range (Swanepoel et.al., 2004). In comparison, the ASSR procedure can reach intensity level of 120dB HL and can therefore detect residual hearing which would not be detected using ABR technique (Swanepoel et.al., 2004, Gorga et.al., 2004).

1.5. Clinical Application of ASSR

1.5.1. Identification of Hearing Impairment

1) As established by various researchers, age has no significant influence on the ASSR measurements, making it highly applicable for subjects from newborn to the elderly (John & Picton, 2000).

2) The use of higher modulation rate (between 70 and 110 Hz) which is resistant against sleep or sedation, making it a method of choice in the assessment of the "difficult to test" population.

3) ASSR is able to obtain reliable hearing thresholds in a time efficient manner because there is no need to sedate or wait for the subjects to sleep before carrying out the test.

4) The recording time is also reduced because of the dichotic multiple presentation of the stimuli. The same time it takes to obtain one threshold in other procedures, in ASSR, eight frequency-specific thresholds can be obtained (Lins et.al., 1996, Picton et.al., 2002, Swanepoel et.al., 2004).

5) ASSR is an objective test, meaning that no behavioural response from the subject is needed and it uses the automated response detection, so no interpretation of results by the clinician is necessary.

1.5.2. Information on Hearing Thresholds

1. Many studies have demonstrated that ASSR is a reliable procedure for estimating behavioural hearing thresholds. The differences between physiological and behavioural thresholds are generally between 5 and 15 dB HL (Perez-Abalo, 2001, Herdman & Stapells, 2001, Dimitrijevic et.al., 2004).

2. ASSR thresholds are presented in the form of an audiogram with the accurate information on the type, degree and configuration of the hearing loss. (Lins et.al., 1996, Rance et.al., 1998, Swanepoel et.al., 2004). This will simplifies the interpretation of the results, and also determine the

appropriate amplification of aided thresholds hence helping in the rehabilitation of the subjects, as well as estimation of cochlear implant candidacy (Picton et.al., 1998, Rance et.al., 1998).

3. The relationship between the ASSR and PTA thresholds increased with increasing intensity and hearing loss severity. The ratio was between 11-15 dB in normal hearing subjects and between 5-13 dB in hearing-impaired subjects (Perez-Abalo et.al., 2001).

4. ASSR able to estimate frequency-specific thresholds at high intensity level (120 dB HL), therefore it is able to estimate accurate thresholds and configuration in subjects with severe to profound hearing losses (Dimitrijevic et.al., 2001).

1.6. Results from past studies

Past studies have shown that ASSR is a reliable method of establishing the auditory thresholds for normal hearing subjects. Lins and Picton (1995) found that in 40 normal hearing subjects, no significance loss in amplitude was detected during the simultaneous stimuli presentation. Perez-Abalo et.al., (2001) also reported that in a study of 40 normal hearing adult the ASSR thresholds were 11-15 dB above the behavioural thresholds. While Herdman and Stapells, (2001) compared the estimation of hearing thresholds in 10 normal hearing adult by implementing different means of presenting ASSR stimuli and found that no significant differences between the different means and recorded the thresholds between 7-14 dBHL.

Initially, researchers doubted that the findings would be similar in the hearing impaired subjects. Lins et.al., (1996) found that variability occur in these subjects at high intensity levels when stimuli were presented simultaneously. However more recent studies by Perez-Abalo et.al., (2001) and Schmulian, (2002) obtained reliable thresholds at high intensity levels in hearing impaired subjects using the multiple presentation. (Swanepoel et.al., 2004). Perez-Abalo and colleagues, (2001) reported that the hearing thresholds in hearing-impaired subjects were between 5 and 13 dB above the pure tone thresholds. While Schmulian compare the thresholds obtained with ASSR and ABR, and found that the degree and configuration of hearing loss is reliably obtained with ASSR (Swanepoel et.al., 2004).

All of these studies were done in European countries, with different demographic and setting than ours, it would be interesting to find out how our results might compare with theirs.

1.7. Rationale of the Study

"Difficult-to-test" population provide the biggest challenge for the clinicians and audiologists alike in coming up with the diagnosis of hearing loss and in managing the rehabilitation. Presently, Pure Tone Audiometry is the gold standard for the frequency-specific threshold audiometry. It depends on behavioural responses, which is deemed unreliable or impossible to obtain in this population.

Both OAE and ABR have been used in this population, especially in the newborn hearing screening programme. OAE can rapidly provide pass/fail result of hearing but unable to describe the level of hearing loss. Only ABR is able to provide auditory thresholds, similar to PTA. However, there are many factors limiting its usage. A lot of time is spent on getting the patients to be ready for the test, sometimes requiring sedation for them to go to sleep. Even with all these measures, patient is still not ready and another appointment has to be made. Sometimes patient will wake up during the test, thus require a repeat of the test at a later date. All these are time-consuming and a waste of resources. Sometimes the PTA machine will break down and patients are unable to be tested.

MASTER (dichotic multiple ASSR) is a new objective procedure available to clinicians and audiologists for the assessment of hearing thresholds. It can provide a frequency-specific thresholds similar to PTA and even able to demonstrate the result in an audiogram form. Only a few centres in Malaysia have this tool. Many studies have demonstrated its applicability in both normal and hearing-impaired populations and in all age groups. It is also a time-efficient procedure because it does not depend on subject state of consciousness and able to test four frequencies in both ears at the same time. Hence more time is dedicated in making the accurate diagnosis rather than waiting for subjects to go to sleep or be sedated.

Presently, no study has been done in Malaysia involving the ASSR / MASTER. Hence this study would like to address the question of the usefulness of this procedure in our clinical setting and whether MASTER is able to provide a comparable result to PTA and thus reliable in its hearing thresholds estimation.

CHAPTER 2

OBJECTIVES OF THE STUDY

2. OBJECTIVES

2.1. General Objective

To compare the measurement of hearing thresholds of MASTER with the Pure Tone Audiometry for both normal and hearing-impaired individuals.

2.2. Specific Objectives

1. To determine the norms of MASTER for the population.
2. To compare response thresholds obtained by MASTER and PTA in normal and hearing-impaired individuals.
3. To prove that MASTER is an accurate predictor of the PTA.