CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

This thesis proposes to study Evoked Otoacoustic Emissions in hearing screening of infants and the effect of external and middle ear status in a group of infants studied at the University Hospital, Kuala Lumpur, Malaysia.

This chapter begins with a brief explanation on the prevalence of hearing loss followed by the relationship between hearing and speech and language acquisition skills. The next section considers early identification and behavioral screening tests followed by the screening of hearing using Otoacoustic emissions. External and middle ear conditions affecting Otoacoustic emissions and the test to determine this is discussed in the following section. Finally the follow up procedure using Auditory Brainstem test on the hearing screening failures are mentioned.

1.1 PREVALENCE OF HEARING LOSS

The prevalence of permanent hearing loss either congenitally or neonatally acquired is approximately 1 in 1000. (Martin et al,1981). In 1995, the World health organization estimated that 120 million people worldwide had a disabling hearing impairment. According to the British medical journal

(1998), an additional two to three per thousand develop profound hearing loss in early childhood. Around 1 in 50 high - risk infants, that is, infants with low birth weight of less than 1500 grams, family history of hearing loss, in-utero infections or infants admitted to the neonatal intensive care unit have hearing loss, and 5 to 6.6 % in 1000 are hard of hearing. Moderate to profound hearing impairment is a serious health problem that occurs more frequently than other diseases.

The mean age for the confirmation of suspected hearing loss is around three years in Europe and United States. In Australia, hearing programs for children have been in existence for more than ninety years. According to the Australian Bureau of Statistics (ABS, 1996), only 17.3% of Australian children aged 0 to 2 years have had their hearing tested and almost one in four children aged 14 years have never had their hearing tested. The result is that for many hearing - impaired children, much of the crucial period for language and speech learning is wasted. For all these reasons, the joint committee on infant Screening issued a position recommending a universal auditory screening to be implemented for all infants within the first 3 months of life.

In Malaysia based on a few random surveys carried out by the Social Welfare Department, it is estimated that there are about 180,000 (1%) disabled persons out of a population of 18 million in Malaysia (Malaysian CARE, 1994). Malaysia has about 18,000 deaf and an additional 90,000 are hard of hearing (Utusan Malaysia, Jan.1995). Recent statistics reveal that there may be up to 100,000 hearing impaired people. Only 15,000 are registered with the National council of Welfare and Social Development (The Sun, Nov. 2000)

1. 2. HEARING AND LANGUAGE ACQUISITION SKILLS

Hearing plays a key role in the development of speech skills as the child progresses through reflexive vocalization, purposeful vocalization and communicative vocalization. The establishment of an association between sounds and movements of speech is essential to this process (Boothroyd,1978). In human beings, the sense of hearing plays a key role in the use and development of verbal language for communication.

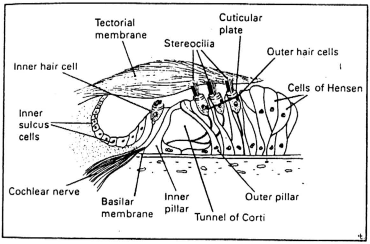
Long ago, the function of hearing became the building stone upon which our intricate human communication system was built. If pre - dawn man had not inherited an ear, he might have resorted instead to signing with his fingers or scratching marks upon the sand, to share his thoughts with others. The result would have been an awkward method of communication that could have slowed, for millennia, our so-called progress. For good or bad, we have developed the ear (Appendix A) and the vocal mechanism as the media through which language is communicated.

In examining communication development in the normally hearing infant and preschooler, one cannot help but marvel at the apparent ease with which skills are acquired and the linguistic proficiency of very young hearing children.The auditory - linked acquisition of language is further unique to human beings because it is a time-locked function, related to early maturational periods in the infant's life. The longer auditory language stimulation is delayed, the less efficient will be the language facility. Critical periods exist for the development of biological functions, and these are responsible for the dependancy of language acquisition on time. A baby who is deprived of appropriate language stimulation during his first 3 years of life can never fully attain his best potential language function, whether the deprivation is from lack of hearing or from lack of high quality language experience (Northern & Downs, 1978).

1. 3. THEORIES OF HEARING

Experimental studies have demonstrated that sounds of very high frequency cause movements of the basilar membrane and the hair cells of the organ of corti at the basal end of the cochlea or, in other words, at the part of the cochlea nearest the middle ear; whereas sounds of very low frequency affect the cochlear duct at the apical end (Fig.1).

Figure1: The hair cells of the organ of corti *(From Handbook of Audiological techniques, Deborah Ballantyne, illustrations by Rita Troisio of Butterworth, Heinemann Ltd. 1990)*

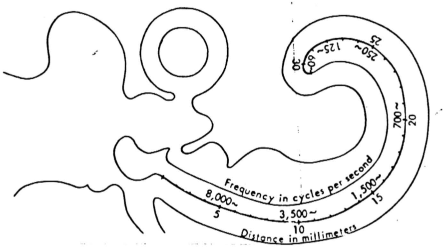


The cochlea's function in analyzing sound can be explained by the principal theories of hearing.

1.3. 1. The Place Theory

The Place theory, originally popularized by the famous German scientist Helmhotz, states that pitch perception is related to the place of maximum stimulation of the basilar membrane.

Figure 2: Location along the basilar membrane of various frequency receptors. The Cochlear is shown uncoiled (*From Audiology, 4th.Edition, by Hayes A. Newby, Prentice- Hall,* Inc.)



Experimental evidence indicates that the basilar end of the cochlea is sensitive to high frequencies and the apical end of the cochlea is stimulated by low frequencies. The Place theory holds that it is the *exact* place of stimulation of the organ of Corti along the basilar membrane that determines the pitch perceived. Helmholz proposed that structures of the cochlear duct act as resonators, much as the strings of a piano vibrate in response to particular frequencies. Later exponents of the Place theory do not believe it is the particular region of stimulation of the basilar membrane that is responsible for the sensation of pitch (Fig 2).

1. 3. 2. The Frequency Theory

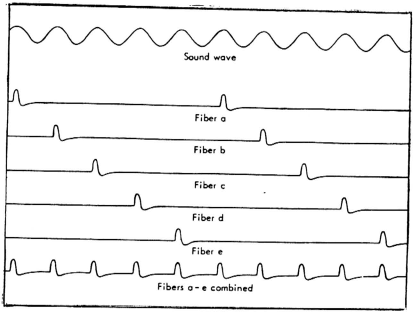
The Frequency theory explains pitch perception on the basis of the frequency of occurrence of impulses in the auditory nerve. Thus, this theory holds that a sound stimulus of a frequency of 500 Hertz (Hz) would cause fibres within the auditory nerve to discharge at the rate of 500 times per second. Rutherford (1949), and more recently Boring (1949) were exponents of this theory. The development of techniques for recording action potentials of nerve fibres disclosed that no fibre of the auditory nerve is capable of "firing" at a rate greater than about 1000 times per second. This experimental finding meant that discrimination of high pitches could therefore not be explained on the basis of the frequency theory. Even making allowance for the synchronized action of several nerve fibres discharging at slightly different times, the frequency theory could account for pitch perceptions only of frequencies below about 5000 HZ.

1. 3. 3. The Volley Theory

The Volley theory is a compromise between the place and frequency theories. It holds that perception of pitch for frequencies up to 5000HZ can be explained primarily on the basis of the frequency of nerve impluses firing in "Volleys" and that the primary explanation for perception of pitch for frequencies in excess of 5000 Hz is the place of greatest excitation along the basilar membrane. The Volley theory was advocated principally by Wever

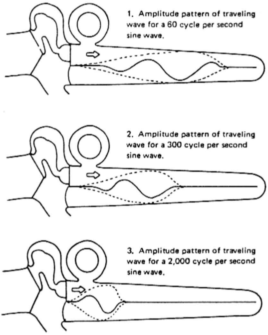
(1949). It utilizes the experimental information available, which does not indicate that place of stimulation within the cochlea is important and which also shows that pitch discriminations are correlated with frequency of nerve impulses, at least for the lower frequencies of sound vibration (Fig. 3).

Figure 3: The Volley principle
(From Audiology, 4th. Edition by Hayes A. Newby, Prentice – Hall, Inc)



1. 3. 4. The Travelling Wave Theory: No discussions of theories of hearing can ignore the contributions of Bekesy George Von(1979), who received the Nobel prize for his many years of detailed and meticulous research in regard to the functioning of the hearing mechanism. Bekesy's experimentation with cochlear models led him to formulate a theory the travelling wave theory that sounds are propagated in the cochlea in the form of a travelling wave in the basilar membrane. This wave travels from the base to the apex of the cochlea. The maximum amplitude of the wave occurs at a point along the basilar membrane that corresponds to the frequency of the stimulus; that is, the point of maximum amplitude is at a point that resonates to the stimulating frequency (Fig. 4).

Figure 4: Travelling Waves along the basilar membrane. *(From Audiology, 4th.Edition, by Hayes A. Newby, Prentice – Hall, Inc)*



The theories of hearing mentioned above are concerned primarily with the way in which the ear discriminates frequency. Intensity discrimination apparently is dependant on the number of nerve fibres activated by the stimulus, the total number of impluses per second in all fibres, and possibly the existence of certain fibres that respond only to stimuli of high intensity.

The tonotopic organization of the auditory system, in which certain areas of the cochlea, eighth nerve, and midbrain auditory nuclei are responsive primarily to certain frequencies and not others, lends support to the assumption that sensory deprivation effects can be frequency specific. Limiting the function of these high frequencies, which carry much of the consonantal energy in speech, has grave implications for speech perception, and thus, language development.

Hearing is one of the modalities through which young babies discover themselves and other people and it therefore contributes to the foundation of social and emotional development. Later hearing provides information about the approach or the presence of other people even when they are not seen. It also serves to convey information about the emotional state of other people through intonation and tone of voice.

It is well documented that the presence of a hearing loss will interfere with the acquisition, development and use of language (Kretschmer & Kretschmer,1978). Clearly the greater the degree of hearing loss and greater the delay in fitting amplification the more difficult it will be for the child to readily acquire language through the auditory channel.

Hearing impairment has perceptual, communicative, speech, cognitive, social, emotional, educational, intellectual and vocational consequences. These are often compounded by the reactions of parents and society, hence the need for intervention. A severe profound loss has direct effects on the development of auditory perceptual skills and linguistic skills. The language defect in turn affects cognitive, social and emotional development. Philosophies of intervention place emphasis on different aspects of the problem and lead to various methodological approaches (Boothroyd, 1982).

1. 4. EARLY IDENTIFICATION AND BEHAVIORAL SCREENING TESTS

Early identification of hearing loss have long been recognized as an important goal for successful language development of the child. Reliable methods for identifying hearing loss are essential. The National Institute of Health, the American Academy of Paediatric, the American Academy of Audiology and the joint committee of Infant Screening have all recommended that children with congenital deafness be identified before six months of age.

Various studies have been carried out to evaluate screening techniques that use observation of a neonatal behavior in response to acoustic stimulation (Gerber,1976). This method of audiometry involves presenting a stimulus to the neonate and then watching the infant for particular gross responses. These responses are subjectively interpreted. They include the startle reflex, arousal from sleep, or the auropalpebral reflex (Downs & Sterrit, 1967). The stimulus is quite intense, usually 60decibel sound pressure level or more.

More automated methods have been developed over the years. They include the 'Crib-O -Gram' and the 'Neonatal auditory response cradle'. These monitor the motions of the infant while they are in the cradle. The Crib-O-Gram involves monitoring the activity of the infant by motion detectors in the crib, for 10 seconds prior to the presentation of the stimulus (Simmons & Russ, 1974). The infant responses are monitored during a stimulus that is, narrow band noise at 3000 Hertz and at an intensity of 90dBSPL. The activity of the newborn is also monitored for approximately 2.5 seconds after the stimulus has ceased.

The Neonatal Auditory response cradle (Shepard,1983) involves monitoring respiratory changes as well as body motions.

As Martin (1981) describes it:

> *"This procedure involves the use of a cradle with a pressure-sensitive head rest and a mattress capable of measuring startle responses to sound through movements of the head, trunk and limbs. A belt is placed around the baby's abdomen to sense changes in respiration. Receivers are placed in the child's ears to deliver the sounds so that response can be observed from the right and left ears separately".*
>
> *Martin. 981:p.170*

This method of screening is slightly more specific when compared to the Crib -O -Gram. It enables the examiner to discern what ear the deficit is in. Once again; the stimulus is quite intense, presented at 85dBSPL at a frequency of noise between 2600 and 4500Hz. Currently, there is controversy over the reliability, sensitivity and specificity of these techniques and the time it takes to administer these tests. The popularity of the Crib-O-Gram and Auditory Response Cradle has declined as they contain several limitations (Durieux-Smith & Jacobson,1985). It has been suggested that behavioral testing can only reliably detect neonates who are profoundly deaf and that it may miss those with mild and moderate hearing loss.

Auditory Brainstem responses can be used to screen for hearing impairment in newborns. Screening infants identified by high - risk register using Auditory Brain Stem response (ABR) has become the standard practice. The screening test is highly sensitive-nearly all children born with significant congenital hearing deficits could be detected in the newborn nursery, however, over- referral is a problem, since there are false - positive ABR's in babies with normal hearing (NIH, 1993)

1.5. OTOACOUSTIC EMISSIONS

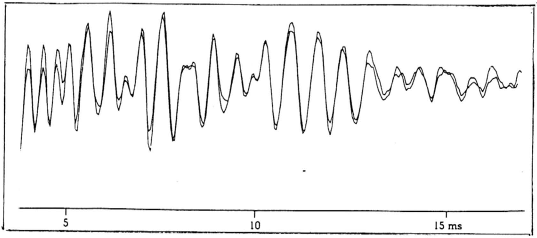
Recently, another possible method has arisen, that of Evoked otoacoustic emissions (EOAEs). The phenomena was first reported in 1978 by David Kemp from the Institute for Laryngology and otology (ILO) in London, England. Studies in adults (Kemp 1978, Kemp et al, 1986, Steven, 1988) have shown that Evoked Otoacoustic emissions can be recorded in most normally hearing adults. Studies in neonates (Johnson et al, 1983, Elberling et al, 1985, Stevens et al, 1987) have shown that the EOAE can be easily recorded in most normal newborns and those admitted to a neonatal intensive care unit (NICU)

Since Otoacoustic emissions (OAEs) were first reported by Kemp (1978), many authors have proposed recording of OAE as a new way of examining peripheral auditory function in infants and children. OAEs are produced by the mechanical movements of the cochlear's most sensitive receptors, the outer hair cells. (OAEs) can be defined as any sound that originates from the cochlea and can be recorded in the outer ear canal (Martin et al, 1990). Vibrations generated inside the cochlea are magnified by the middle ear and transmitted into the air as sound.

OAE take various forms depending on the stimulus conditions (Kemp et al, 1986), but as far as we know, they all originate in the same hair cell mechanism. It should be well understood that OAEs are not restricted to experimental situations, but that they are a natural physiological accompaniment to normal hearing.

The most general way to evoke OAEs is to provide a very short but strong stimulus, which is repeated about every 20milliseconds. Click stimulated OAEs can be processed to provide cochlear information over a wide range of frequencies simultaneously, which brainstem evoked response, for instance, cannot. This method conveniently separates stimulus and response in time, like an echo. The latency of human EOAEs is between 5 and 15 msecs as shown in Figure 5, which shows a typical click evoked otoacoustic emissions.

Figure 5: A typical click- evoked otoacoustic emission. *Two repeat recordings are superimposed to illustrate reproducibility. The start of the time axis is the onset of the click stimulus*



1. 5. 1. Types of Otoacoustic Emission (OAE) phenomena

There are 2 basic otoacoustic emission phenomena :

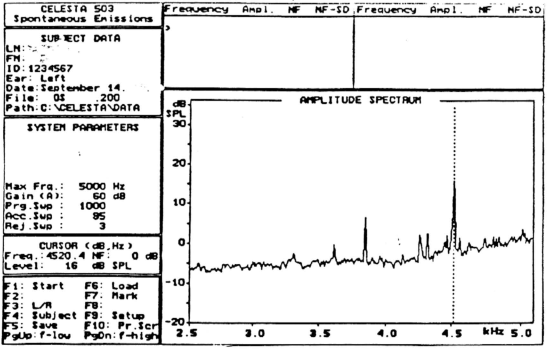
1. Spontaneous Otoacoustic Emissions (SOAEs)
2. Evoked Otoacoustic Emissions (EOAEs)

1. 5. 1. 1. Spontaneous Otoacoustic Emissions (SOAEs).

Spontaneous emissions occur in the absence of external stimulation. The SOAE test is designed to characterize sound pressure level in the absence of deliberate acoustic stimulation. In about 50% of normal hearing ears, low amplitude, narrow band signals known as spontaneous otoacoustic emissions will be detected at one or more frequencies.

The small microphone in the system probe detects these signals. The output from the microphone is amplified and the response subjected to spectral analyses. In other words, a time recording is made of the sound pressure level in the ear canal. This is transformed into the frequency domain by Fast Fourier transform FFT analyses. The process is repeated as specified in the test protocol, the average is calculated and the results are displayed. An example of an SOAE response is shown in Figure 6.

Figure 6: An example of an SOAE response (SOAE)



1. 5.1. 2. Evoked Otoacoustic Emissions (EOAEs)

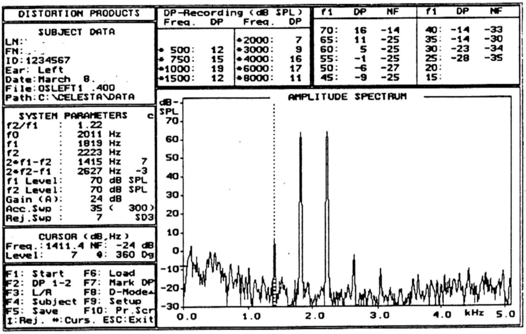
Evoked otoacoustic emissions which occur in nearly all normal hearing, are further divided into three sub- types according to the nature of the acoustic stimulus used to elicit them.

- Transient Otoacoustic Emissions (TEOAEs) occur in response to brief acoustic signals (clicks, tone bursts etc).

- Distortion Product Otoacoustic Emissions (DPOAEs) (Fig. 7) are evoked by two simultaneously presented pure tones of different frequencies. Specifically, if two tones of frequencies F1 and F2 (F2>F1) are presented externally, a third tone of frequency 2 F1–F2 will be produced internally. They represent the ear's nonlinear responses to the stimulus tones and consist of new frequencies not present in the eliciting stimuli. Although DPOAEs are somewhat more complex to elicit and analyse than TEOAEs they may have greater clinical utility for some applications as in objective predictors of pure tone hearing threshold. An example of a DPOAE response is shown in Figure 7.

- Stimulus-Frequency Otoacoustic Emissions (SFOAEs) are the most frequency specific, occuring simultaneously with and at the same frequency of the eliciting stimulus. They reflect the response of the cochlear to pure tone input, however, because their detection is more complicated and time consuming than the measurement of TEOAEs, they have not yet been incorporated into clinical tests.

Figure 7: Distortion Products otoacoustic emission. *Example of a DP response. F1 and F2 are the stimuli and 2F1 - F2 is the emission generated by the cochlear*



1. 5. 2. Idenitifying Evoked Otoacoustic Emissions.

It is important to be sure that a sound in the ear canal is an EOAE, especially in the clinical situation. Its unique properties allow us to separate the EOAE from the stimulus sound, from the acoustic response of the middle ear and from patient noises.

By varying the stimulus intensity, we can identify EOAE by its saturating non - linear growth. Using stimuli with rapidly fluctuating intensity, such as two beating tones, non- linear processing results in distortion products which can be easily separated from the from the stimulus by spectrum analysis. Latency provides another very powerful method to identify EOAEs. Recording systems can be designed which make use of only ear canal sounds that are appropriately delayed with respect to the stimulus. OAEs can be used to study Cochlear function in an objective and non invasive manner. These features of emitted responses have stimulated a great deal of investigation into the utility of evoked emissions as clinical tests of hearing.

1. 5. 3. Click / Transient Evoked Otoacoustic Emissions

The most commonly studied form is the evoked Otoacoustic emissions recorded following a click, also referred to as the Transient Evoked Otoacoustic emissions (TEOAE). These are frequency dispersive responses following a brief acoustic stimulus, such as a click or tone burst. Because this was the first emission type reported in the literature by Kemp (1978), the term *evoked otoacoustic emissions (EOAE)* is often applied specifically to transient evoked emissions. They are also known as *Kemp echoes, cochlear echoes* and *delayed evoked otoacoustic emissions.* An example of a normal and an abnormal non- linear transient OAE are shown in figures 8 and 9 respectively.

TOAEs are obtained by using synchronous time-domain averaging techniques similar to those used to measure auditory evoked potentials. By sealing a receiver microphone probe into the ear canal, sounds made by the cochlear can be evoked by external sound and recorded from almost any ear with normal middle frequency hearing. One of the most important characteristics of the response is that it is frequency dispersive-high frequencies emerge sooner, (that is have a shorter latency) than low frequencies. This frequency dispersion is consistent with frequency coding along the basilar membrane, that is high frequencies are coded basally, whereas low frequencies are coded apically. TEOAEs are measurable in essentially all normal middle ears and normal cochlear's (Kemp,1978, Johnsen and Elberling, 1982, Grandori et al, 1985)

Figure 8: Example of a Normal Non- Linear Transient evoked otoacoustic emission (TEOAE). *Top left shows the stimulus waveform and below the TEOAE waveform. Top right shows the energy spectrum of the response (upper, open) and of the noise floor (lower, shaded).*

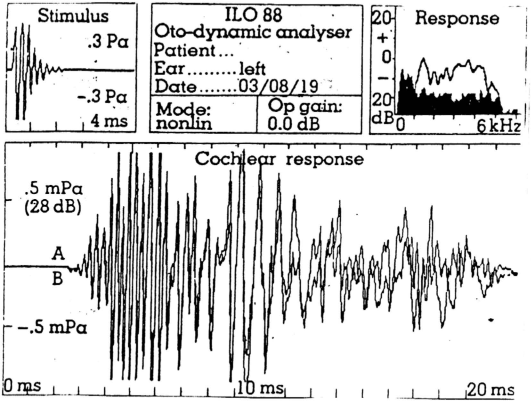
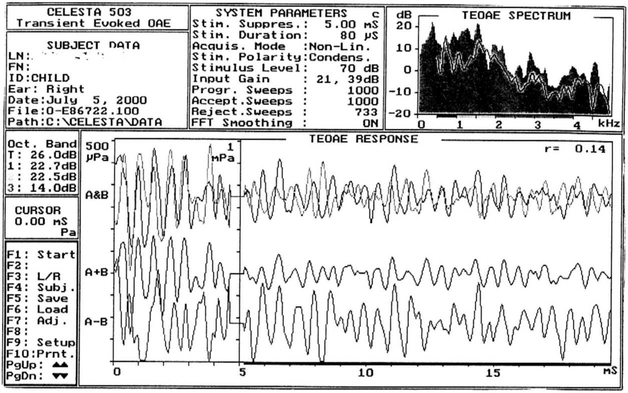


Figure 9: Example of an Abnormal Non – Linear Transient evoked otoacoustic emission (TEOAE). *The lower right third of the screen displays the time domain waveform in three traces. The TEOAE spectrum in the upper right corner of the display is a representation of the response amplitude by frequency.*



Much of the clinical work related to OAEs has focused on click evoked emissions. This is primarily because they provide a broad band cochlear-wide information. TEOAES are clinically adequate in separating normal from hearing impaired subjects, On the other hand they do not give significant information concerning the amount of hearing loss. When a threshold estimation is needed, other tests must be performed such as the (ABR). This means that the test cannot be used to measure hearing thresholds, or to distinguish between cochlear and conductive hearing loss. OAEs do however have great potential as a screening test.

The audiological investigations in infants is probably the main clinical issue that has been studied with TEOAEs (Johnsen et al 1988, Elberling et al 1985).It was hypothesised that the relationship between (TEOAE) signals and the functional status of the outer hair cells provides an opportunity to design a clinical picture that can evaluate the normality of cochlear function.

1. 5. 3. Otoacoustic Emissions and external / middle ear conditions

It is also important to note that in testing cochlear function, EOAE can also assess the conductive status of the middle ear. According to Pickles (1988), the structural properties of the external and middle ear effect sound transfer to the cochlear and therefore will affect OAEs. External and /or middle ear conditions are known to affect the outcome of EOAE test. EOAEs are very sensitive to middle ear pathology due to the significant impact of the resulting middle ear changes on the reverse transmissions of acoustic energy to the ear canal (Pickles, 1988).

Emissions have been shown to be absent in the presence of significant middle ear effusions, and in the majority of cases to be reduced or absent with negative middle ear pressure. The technique is tolerant to a moderately abnormal middle ear pressure but not to fluid. OAEs may be affected by the presence of fluid in the middle ear, negative middle ear pressure, debris in the external ear canal, lack of ventilation in the middle ear space immediately after birth, otitis media or inflammation of the middle ear.

1. 6. TYMPANOMETRY TEST

Middle ear conditions can be assessed by performing the middle ear function test known as Tympanometry. It is the objective measurement of the effect of varying air pressure on the mobility of the middle ear system. The Tympanogram, the graphic result of tympanometry shows the change in compliance or mobility of middle ear system as air pressure is varied in the external ear canal. In physical terms, the external and middle ears can be represented as two separate cavities divided by a thin elastic membrane, Each of the cavities is characterized by its volume expressed in cubic centimetres.

The basic concepts should be kept in mind. ***Impedance*** is the degree of resistance offered by a given system to the flow of energy. ***Admittance*** is the ability of the system to absorb such energy and is expressed in terms of ***compliance.*** Since it is directly related to the volume of the measured cavity, compliance is also an expression of its volume.

If the normal resting tension in the ear drum and middle ear ligaments is altered as is known from tympanometry test, the general consequences of these changes is an increase in the stiffness of the middle ear together with slight reduction in its acoustic transmission particularly at low frequencies. It is therefore expected that otoacoustic emissions will be affected both by a reduction in the effective stimulus and by impaired transmission of the response through the middle ear. Furthermore displacement of the middle ear structures will change the acoustic impedance at the oval window as seen from within the cochlea and this in itself is likely to influence the mechanical response.

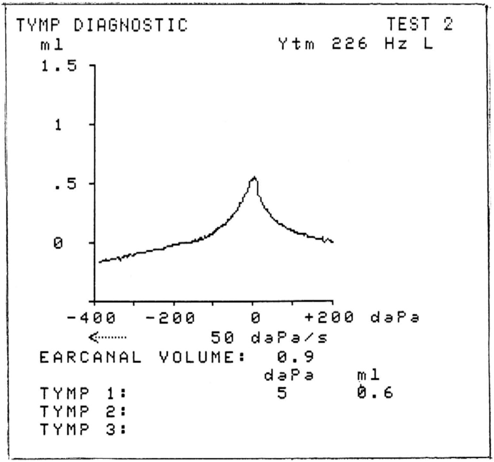
Tympanic membrane / ear drum mobility is of particular interest since almost any pathology located on or medial to the eardrum will influence its movement. The Otolaryngologist routinely creates air pressure against the eardrum with a pneumatic otoscope and makes subjective judgments regarding the mobility of the ear drum. Tympanometry however is more objective than the Otolaryngologist's eye and the pressure involved with the technique are very small compared with air pressures created with an otoscope. Often eardrums noted to have normal mobility by otoscopy examination can be shown to have abnormal mobility with tympanometry.

The mobility of the eardrum is at its maximum when air pressures on both sides of the eardrum are equal. That is the eardrum achieves its best mobility when the air pressure in the external auditory canal is exactly the same as the existing air pressure in the middle ear. The presence of unequal pressures on either side of the eardrum usually occurs when negative pressure exists in the middle ear space. This may be sufficient to cause a retraction of eardrum accompanied by mild conductive loss. An example of this occurs when air pressures are changed in passenger cabins in an aircraft.

1. 6. 1 Classification of Tympanograms

Several procedures for classifying and interpreting tympanograms have been proposed over the last 2 decades. Early classification systems categorized tympanograms on the basis of shape and tympanogram peak pressures. The most commonly used classification was introduced by Liden (1969) and modified by Jerger (1970). For simplicity, Jerger ascribed alphabetical letters to each type of curve, Tympanogram Type A, Type Ad, Type As, Type B, Type C, and Type D.

Figure 10: Tympanogram Type A



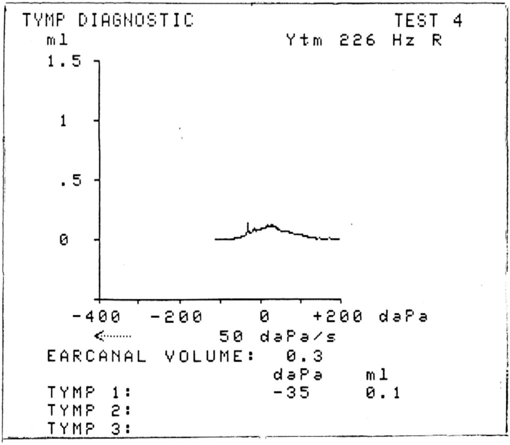
1. 6. 1. 1. Tympanogram Type A

The normal Type A Tympanogram shows a sharp peak of maximum mobility at or around 0 mm H20, indicating a middle ear system with a normal air filled middle ear able to transmit sound maximally. Alberti and Kristensen (1970) recommended the use of +_ 50 mm H2O as normative values (Fig.10)

1. 6. 1. 2. Tympanogram Type As

This pressure – compliance function is characterized by normal middle ear pressure and limited compliance relative to the mobility of the normal tympanic membrane. The "S" nomenclature is indicative of "stiffness", or "shallowness" of the tympanogram (Fig. 11).

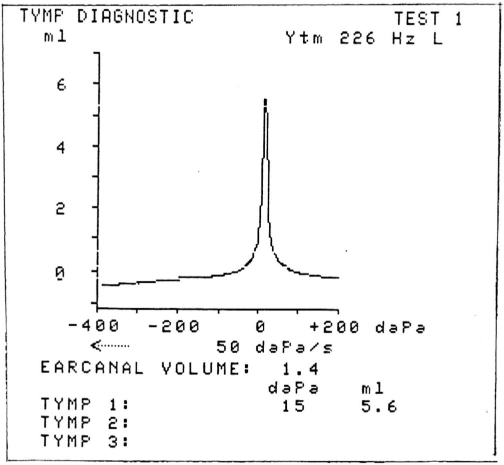
Figure 11: Tympanogram Type As



1. 6. 1. 3. Tympanogram Type Ad

This curve is represented by large changes in relative compliance with small changes in air pressure. The Type Ad is noted in middle ears where discontinuity of the ossicular chains has occurred. The ' d ' indicates a " deep" tympanogram curve (Fig. 12)

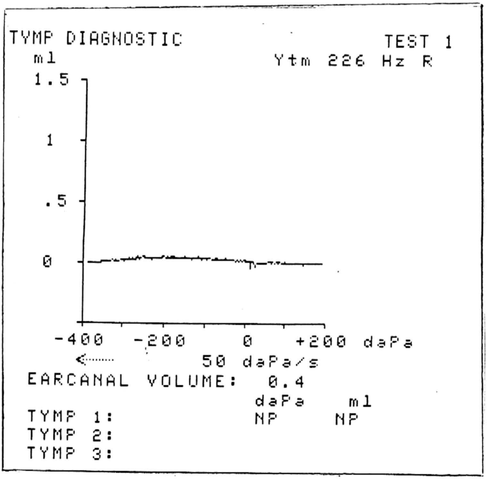
Figure 12: Tympanogram Type Ad



1. 6. 1. 4. Tympanogram Type B

The type B tympanogram is characterised by a function representing little or no change in compliance of the middle ear as air pressure in the external ear canal is varied. The tympanogram is flat and occurs in the presence of middle ear effusions. The curve is also noted in patients who have perforations of the tympanic membrane, and ear canals totally occluded with wax. Type B pattern can also be seen in cases of tympanic membrane perforation and impacted cerumen (Fig. 13).

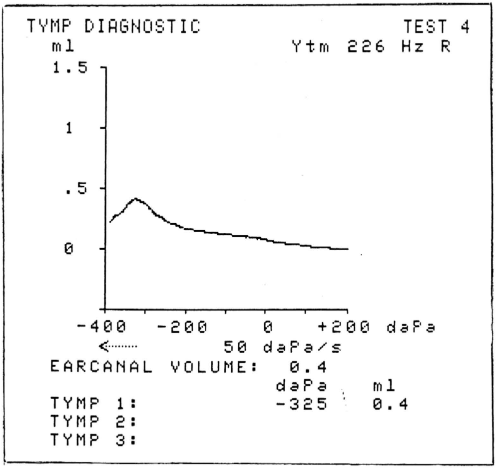
Figure 13: Tympanogram Type B



1. 6. 1. 5. Tympanogram Type C

The type C tympanogram is represented by near normal compliance and negative tympanometric peak pressure indicating negative ear pressure in the middle ear which is outside the range of normal +50 to - 100 mm/H20. This curve is seen in Eustachian tube dysfunction in the presence of an intact eardrum (Fig. 14).

Figure 14: Tympanogram Type C



1. 7. USEFUL PROPERTIES AND APPLICATIONS OF OTOACOUSTIC EMISSIONS

1. 7.1 Screening Applications:

One of the most useful current applications of TEOAEs is in the screening of hearing in the newborns. It is well established that less than 1 percent of newborn infants i.e.1-2/1000 are born with a profound hearing loss. Unfortunately the average age for identifying the hearing loss can be up to 2.5 years of age, because of the difficulty in detecting these infants among the thousands of yearly birth.

Previously tested procedures,such as Behavioral Audiometry have not been shown to be effective.Thus the strategy of using TEOAEs to test neonates to achieve a rapid pass or/fail decision that reveals whether the threshold of hearing is less than, or greater than 30 dBHLhas been proposed and tested in a number of situations.

The clinical applications of OAEs have been the subject of many scientific researches. Early detection of hearing loss in neonates and infants *is one of the established applications. Auk et al (1993) reviewed the technical* and practical overall advantages of a neonatal hearing screening program using OAE technology. They concluded that its simplicity, rapidity, non-invasiveness, objectivity, sensitivity and cost effectiveness make it suitable for such a task.

1.7. 2 Other Applications

OAE display a number of features that makes them ideal for clinical testing. Firstly, they are objective measures that can be used to examine difficult to test patients, young children, the critically ill and the mentally incompetent or non - cooperative patients. The property of objectivity is also compatible with computer control of the test procedure which permits it to be conducted rapidly and accurately. In addition OAE testing is relatively inexpensive. The initial equipment needed is an economical personal microcomputer with commercially available software and interface components.

Measurement of OAEs is non-invasive using a probe tip that contains one or more ear speakers and /or microphones. Insertion of the probe tip snugly into the ear canal is performed quickly so that the patient sit up time is minimal. This benefit of emissions testing is particularly desirable in examining very young patients who are often restless and irritable.

Another advantage of OAEs is that testable emissions are present in the case of nearly all normally hearing persons and are reduced or absent in ears exhibiting impairment caused by cochlear or middle ear dysfunction. Normal response ranges have been established over the past several years allowing assessment of the healthiness of an unknown ear on the basis of comparing its emissions properties to the database of normal response.

An additional positive attribute of OAE is their known origin in the pre neural region of the organ of corti. Thus OAE results provide specific knowledge concerning the contribution that sensory elements make to hearing impairment. The availability of this information in combination with the findings of other audiological tests, permits the unambiguous determination of the sensory versus neural components of a sensorineural hearing loss. Of all the structural elements in the cochlear, outer hair cells (OHCs) are most vulnerable to the damaging effects of excessive noise and ototoxic drugs as well as to the more insidious consequences of natural aging, viral and bacterial pathogens, congenital factors and genetic defects. Because emissions are a specific measure of OHC function OAE testing is highly sensitive to these common forms of damage.

The OAE are also sensitive to early stages of hearing impairment, because they operate maximally in response to low and moderate level stimuli. Additionally, emissions provide a direct measure of the non-linear operations of the cochlear that are responsible for the ear's remarkable processing capabilities in response to low-level sounds.

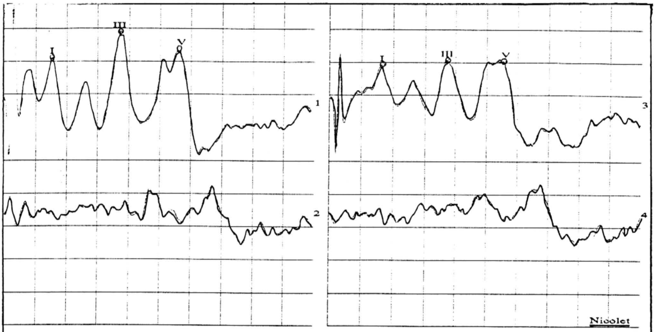
1. 8. AUDITORY BRAINSTEM RESPONSE TEST (ABR)

Since first described, the ABR technique for recording a neural response at the brainstem to an auditory input, has become a powerful tool to objectively evaluate hearing in both infants and adults. Auditory brain-stem response testing is not a measure of hearing, but requires the detection of sound – initiated neural activity from the scalp, and hearing occurs with the conscious perception of sound. Even though the ABR is not a measure of sound, ABR recording can be tied closely to behavioral thresholds of hearing.

This test has allowed the evaluation of auditory function in newborns, obtained ear specific information on infants under 6 months of age and verified questionable behavioral responses obtained in difficult to test children. A click stimulus presented through air conduction, which provides information in the 2000 to 4000Hz region, is recorded by electrodes placed on the patient's head. The ABR is optimally recorded differentially from the vertex to either mastoid with an electrode on the contralateral mastoid serving as ground. The ABR is most easily evoked with transient stimuli (clicks) repetitively presented and subsequently summated by computer analysis. Click stimuli provide a sufficiently short rise time to ensure a synchronous neural burst from the auditory system (Hecox et al, 1976).

In response to the click stimulation, there are five waves or peaks that appear in normal hearing infants and adults (Fig.15a) within the first 10 milliseconds after presentation, and reflect responses from the auditory nerve and brainstem nuclei. The fifth peak, known as wave V, is usually the most prominent wave when identifying minimal response levels. At higher stimulation levels in normal hearing children (70 to 80dBnH) absolute and interwave latencies can be measured for waves 1 through V; in infants wave 1, 111 and V, however, may be the only waves that can be identified. Auditory brainstem responses obtained on children over 18 months can be compared to normal adults.

Figure 15 a: Auditory Brainstem Response (ABR) – *Normal Pattern.*
Example of ABR peaks as a function of stimulus intensity at 80 and 30 dBHL



Sensitivity and Sweep Time Per Division

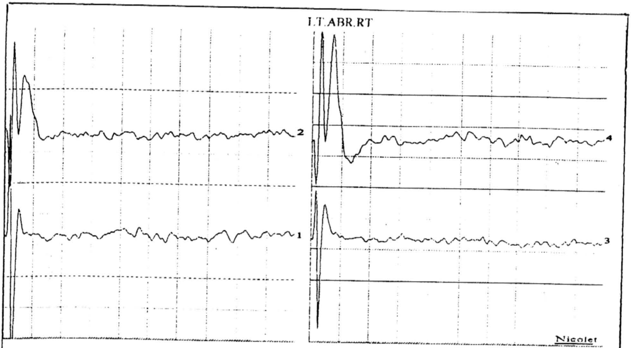
1	0.25 uV	1.0 msec	2	0.25 uV	1.0 msec	3	0.25 uV	1.0 msec	4	0.25 uV	1.0 msec

ABR

I	1.52ms	I-III	2.20ms	I	1.64ms	I-III	2.08ms
		III-V	1.88ms			III-V	1.80ms
II		I-V	4.08ms	II		I-V	3.88ms
III	3.72ms			III	3.72ms		
IV		V/I		IV		V/I	
V	5.60ms			V	5.52ms		
contra V				contra V			

Figure 15b: Auditory Brainstem Response (ABR)- *Abnormal Pattern*

Example of ABR peaks as a function of stimulus intensity at 80 and 100dBHL



Sensitivity and Sweep Time Per Division

1 0.25 uV 1.0 msec 2 0.25 uV 1.0 msec 3 0.25 uV 1.0 msec 4 0.25 uV 1.0 msec

MP	Elect	Mode	Sns	LfT	HfT	Notch	Artifact	REM	Remarks
1	Cz-A1	Run	20uV	100	3K	Off	90	1	
2	Cz-A1	Run	20uV	100	3K	Off	90	2	
3	Cz-A2	Run	20uV	100	3K	Off	90	3	
4	Cz-A2	Run	20uV	100	3K	Off	90	4	

CQ	Comm	Sweep	Time	Delay	Rate	Trigger	Stim	MISC	Type	Ch#	Accept	Reject	Filter	Esp/SNR	Date	Time	Add	Sub	Inv
1	A	1500	10ms	0ms	11.1	Inter	Gated	1	Sum	1	1149	4	Butter	-30.38dB	01/29/2001	11:10	no	no	no
2	A	1500	10ms	0ms	11.1	Inter	Gated	2	Sum	1	1236	1	Butter	-25.66dB	01/29/2001	11:14	no	no	no
3	A	1500	10ms	0ms	11.1	Inter	Gated	3	Sum	1	1500	0	Butter	-34.74dB	01/29/2001	11:25	no	no	no
4	A	1500	10ms	0ms	11.1	Inter	Gated	4	Sum	1	1324	36	Butter	-26.58dB	01/29/2001	11:29	no	no	no

1. 8. 1. Applications of ABR

ABR is utilized in these areas of Paediatric audiologic measurement:

- In screening.
- In contribution to the auditory evaluation of infants too young for definition of hearing status through behavioural testing.

Hearing screening programs using OAEs have been conducted at the University Hospital, Malaysia, since 1997. Previously, screening infants using behavioral auditory assessment and identification by high - risk register using Auditory Brainstem response (ABR) test was the standard practice of screening infants. Studies on this particular population group that is between the ages of 2 months to 2.6 years have not been reported in Malaysia.

2. 0. PURPOSE OF THE STUDY

This research attempts to determine if EOAE is a sensitive test and can be used as the first step in the screening of hearing in a population of infants. This study also proposes to look at the influence of external and middle ear conditions/status affecting Transient (click) evoked Otoacoustic emissions in a group of infants studied in university hospital. Specifically the following research questions would be answered:

1. Is there a relation between Transient evoked otoacoustic emissions (TEOAE) screening scores and external / middle ear conditions?
2. To what extent does TEOAE test successfully identify infants with hearing loss?
3. Is there a significant number of infants detected having sensorineural in the OAE screening?

2. 1. SIGNIFICANCE OF THE STUDY

First, this study intends to create an awareness on the need to have hearing screening techniques for the identification of hearing impairment in children by using an objective, rapid, accurate and cost effective procedure. Traditional methods of screening infants have limitations with their accuracy in detecting children with hearing loss.

Secondly, this study highlights the importance of including ear examination and tympanometry test as important components of the hearing screening process.

2. 2. LIMITATIONS OF THE STUDY

The present study is based mainly on Tympanometry and interpretation of the Tympanograms to assign to group A and group B to determine the presence or absence of external and middle ear conditions/status of the ear.

Since a precise diagnosis of the external/middle ear conditions was not necessary in this study, Otoscopic examinations of the ear was not given emphasis for analysing the external and middle ear conditions.

For the documentation of the results of the TEOAE screening, the present study used only a subjective rating of the recorded waveforms on a scale from 0 (absent) to 4 (very clear emissions). The intention was to perform a general screening test for assessing the hearing status in infants, and this was proven to be adequate for screening hearing as reported by Lutman ME (1989) in his study.

2. 3. 0. DEFINITION OF TERMS

The following are terms used in this study and their respective meanings:

2. 3. 1. Congenital Loss

Hearing Impairment present at birth

2. 3. 2. Profound deafness

Deafness in which the average threshold level for frequencies 500,1000 and 2000Hz are 91 dB plus

2. 3. 3. Middle ear effusion

Presence of fluid in the middle ear.

2. 3. 4. Otitis Media

Inflammation of the middle ear.

2. 3. 5. Acoustic Impedance

The degree of resistance offered by a given system to the flow of energy.

2. 3. 6. Bio– neuro electric potentials

Pertaining to electric phenomena in body tissue

2. 4. 4. Hypoxia

Oxygen deficiency at birth resulting in hearing impairment. It is a significant peri-natal cause of hearing loss.

2. 4. 5. Ototoxicity

Drugs that primarily affect the cochlear resulting in hearing impairment.