Role of Transient Evoked Otoacoustic Emission Beyond Screening of Hearing Impairment: A Study of 400 Cases

Rakesh Singh Meena · Deepali Meena ·
Dinesh Babu · B. K. Singh · P. C. Verma

Received: 18 March 2012 / Accepted: 10 November 2012 / Published online: 13 December 2012
© Association of Otolaryngologists of India 2012

Abstract The primary purpose of this study was to investigate the potential role of transient-evoked Otoacoustic emissions (TEOAEs) beyond screening for hearing impairment in different middle/inner ear disorders in 3–65 years age group. Because TEOAEs are present in ears with normal cochlear and middle ear function and typically are absent or reduced in ears with cochlear and/or middle ear disorders of even mild degree. This was a prospective study of four hundred cases. Out of these 364 cases were having problems related to otology and 36 were healthy volunteers who attended the department of otorhinolaryngology of our institute. All the cases were kept in different eight groups and then subjected to Otoacoustic emission testing with the ‘GSI AUDIO screener’ equipment installed in our ENT department. The data obtained in all groups were analyzed and conclusion was made. TEOAEs is a reliable, simple and cost effective screening technique for hearing disorders with sensitivity varying from 72 to 96.42 % among the study groups and 88 % in composite group comprising all study groups.

Keywords TEOAEs—transiently evoked Otoacoustic emission · GSI AUDIO screener · OAE testing instrument · Otosclerosis · Presbycusis · REFER · PASS

Introduction

Otoacoustic emission testing (OAE) is the recording of sounds that the ear produces itself. Otoacoustic emissions were first reported by David Kemp in 1978. They appear to be generated by motile elements in the cochlear outer hair cells [1].

There are two types of Otoacoustic emissions in clinical use:

Transient Otoacoustic emissions (TOAEs) or transient evoked Otoacoustic emissions (TEOAEs): Sounds emitted in response to an acoustic stimulus of very short duration; usually clicks but can be tone-bursts.

Distortion product Otoacoustic emissions (DPOAEs): Sounds emitted in response to 2 simultaneous tones of different frequencies.

OAEs are measured by presenting a series of sounds to the ear through a probe that is inserted in the ear canal. The probe contains a loudspeaker that generates the sounds and a microphone that measures the resulting OAEs that are produced in the cochlea and are transmitted through the middle ear into the outer ear canal. The resulting sound that is picked up by the microphone is digitized and processed by the instrument.

To obtain an OAE one needs an unobstructed outer ear canal, absence of significant middle ear pathology, and functioning cochlear outer hair cells. Thus OAE has some role in assessing the otological disorders like otitis media with effusion, chronic suppurative otitis media (CSOM), otosclerosis, deaf mutism, presbycusis, vertigo, and tinnitus [1]. In this study we are using OAE as diagnostic tool for different otological diseases and final diagnosis was confirmed by clinical findings, tuning fork test, pure tone audiogram, tympanometry, brain stem evoked response audiometry. Thus sensitivity, specificity, positive predictive

R. S. Meena (✉) · D. Meena · D. Babu ·
B. K. Singh · P. C. Verma
Jawaharlal Nehru Medical College, B-534, Panchsheel Nagar,
Makadwadi Road, Ajmer, Rajasthan, India
e-mail: rakeshmeenaent@yahoo.in

value and negative predictive value of different disorder were calculated to know the role of OAE in diagnosing the different otological disorders.

Materials and Methods

The present study “Study of Transient Evoked Otoacoustic Emission as a screening technique for hearing loss” was conducted in the outpatient wing of the Department of ENT, JLN medical College, Ajmer, Rajasthan, on randomly selected 364 cases of hearing disorders (diagnosed by history of present illness, clinical findings, pure tone audiogram, tympanogram, Brain stem evoked response audiometry, Tuning fork tests) and randomly selected 36 healthy volunteers (who were normal on otological examination and their pure tone audiogram was normal) as controls (i.e. making a total of 400 individuals in the study group) who attended the OPD. After proper history and otorhinolaryngological examination (especially ear examination with speculum, otoscope, and microscope), tuning fork test, pure tone audiometry and tympanometry and brain stem evoked response audiometry (only in required cases) were done to established diagnosis. Then the cases were grouped into eight groups as given below

1. Normal controls.
2. Diagnosed cases of deaf-mutism.
3. Patients with middle ear effusion.
4. Patients with CSOM.
5. Patients with otosclerosis.
6. Patients with presbycusis.
7. Patients with tinnitus.
8. Patients with vertigo.

All the test candidates were subjected to detailed clinical evaluation with special reference to gestation and obstetric history, birth history, treatment history, family history of deafness, development of mile stones, history of present illness, routine general physical examination and thorough ENT checkup to find out any associated factor leading to hearing impairment. Finally the case was subjected to Otoacoustic emission testing. Otoacoustic emission testing was done with the ‘GSI AUDIO screener’ equipment installed in the ENT department. All these were recorded in a specially prepared proforma.

The testing for Otoacoustic emissions was done without any sedation for the co-operative patients, but pediatric unco-operative patients were sedated with syrup promethazine.

Those patients who failed in the first Otoacoustic emission testing were examined for confounding factors like occlusion of external auditory canal or collapsible external auditory canal, and were re-examined with Otoacoustic emission testing. The Otoacoustic Emission testing

was done in the sealed, air-conditioned room of the ENT department. Repetitions of the tests were done to avoid errors and ensure reproducibility of the results.

In each group, based on the clinical and audiological examinations including Otoacoustic emission testing, further classifications were made as below

1. *True positives*: The cases which have been diagnosed as having hearing threshold of 30 dB or worse, and in which OAE testing showed “REFER”.
2. *True negatives*: The cases which have been diagnosed as having normal hearing or hearing threshold of 30 dB or better, and in which OAE testing showed “PASS”.
3. *False positives*: The cases which have been diagnosed as having normal hearing or hearing threshold of 30 dB or better, and in which OAE testing showed “REFER”.
4. *False negatives*: The cases which have been diagnosed as having hearing threshold of 30 dB or worse, and in which OAE testing showed “PASS”.

To ascertain the efficiency of TEOAE testing as a reliable diagnostic test for hearing disorders, the following parameters have to be calculated.

1. *Sensitivity*: It is the ability of a diagnostic test to positively identify a case from those having the disorder. It is calculated by the formula

$$\text{Sensitivity \%} = \frac{\text{True positives} \times 100}{\text{True positives} + \text{false negatives}}$$

2. *Specificity*: It is the ability of a diagnostic test to negatively identify a case from those not having the disorder. It is calculated by the formula

$$\text{Specificity \%} = \frac{\text{True negatives} \times 100}{\text{True negatives} + \text{false positives}}$$

3. *Positive predictive value*: It is the diagnostic power of the test. It is the probability of a person with a positive result, in fact, having the disease in question. It is calculated by

$$\text{Positive predictive value} = \frac{\text{True positives} \times 100}{\text{True positives} + \text{false positives}}$$

4. *Negative predictive value*: The probability of a person with a negative result, in fact, not having the disease in it is question. It is calculated by

$$\text{Negative predictive value} = \frac{\text{True negatives} \times 100}{\text{True negatives} + \text{false negatives}}$$

The important parameters of a screening test are the sensitivity and the positive predictive value. The data of

various groups after OAE testing were analyzed to find out the above parameters and based on these parameters conclusions are made. On completion of the study the cases were explained of their disease and necessary advice regarding treatment and rehabilitation were given.

Observations

A total of 528,150 patients attended the out patient departments of our hospital during the study period out of this 2,178 were having hearing problems. The prevalence of hearing problems in hospital attending population was 0.412 %. In different analysis we are using no. of ears (no. of ears = 2 × no. of patients).

Age and Sex Distribution

Out of the 400 cases examined 220 (55 %) were male and 180 (45 %) were females of 3–65 years of age group.

Socio Economic Status

In our study of the 400 cases it was found that 256 (64 %) were from the low socio economic status and 144 (36 %) were found to be from middle/upper socio economic status.

Rural/Urban Status

In study group of 400 individuals 272 (68 %) were from rural areas and 128 (32 %) were from urban areas.

Data analysis of cases of otitis media with effusion (Tables 1)

Sensitivity = $72 \times 100/72 + 28 = 72 \%$.

Specificity = $28 \times 100/28 + 8 = 77.77 \%$.

Positive predictive value = $72 \times 100/72 + 8 = 90 \%$.

Negative predictive value = $28 \times 100/28 + 28 = 50 \%$.

The high sensitivity and positive predictive value are suggestive of the feasibility of TEOAE testing as a suitable screening test for suspected cases of otitis media with effusion.

Table 1 Data analysis of cases of otitis media with effusion

OAE abnormality	No. of ears with disease	No. of ears without disease	Total
OAE test positive	72 (true positive)	28 (true negative)	100
OAE test negative	28 (false negative)	8 (false positive)	36
Total	100	36	136

Data analysis of cases with deaf mutism (Tables 2)

Sensitivity = $216/216 + 8 \times 100 = 96.42 \%$.

Specificity could not be calculated in this group as all ears were involved ones.

Positive predictive value = $216 \times 100/216 + 0 = 100 \%$.

The data shows high values for sensitivity and positive prediction (96.42 and 100 % respectively). As deaf mutism if not detected and proper rehabilitation measures are not taken in time, can cause severe handicap and deny the child a quality life. As the data of the present study suggest TEOAE is a suitable test which would serve the purpose with meticulous accuracy.

Data analysis of cases with CSOM (Tables 3)

Sensitivity = $32/32 + 8 = 80 \%$.

Specificity = $20/20 + 4 = 83.3 \%$.

Positive predictive value = $32 \times 100/32 + 4 = 89 \%$.

Negative predictive value = $20 \times 100/20 + 8 = 71.4 \%$.

CSOM is a very common ear problem in our society. Long standing cases of CSOM can have deleterious effect on hearing due to two reasons. (1) Conductive hearing loss due to TM perforation and erosion/fixation of the ossicular chain. (2) Sensori neural hearing loss due to toxin mediated cochlear damage.

TEOAE test detects the status of the cochlea and is a good screening tool in these cases.

Data analysis of cases with otosclerosis (Tables 4)

Sensitivity = $72/72 + 8 \times 100 = 90 \%$.

Specificity = $8/8 + 8 \times 100 = 50 \%$.

Positive predictive value = $72 \times 100/72 + 8 = 90 \%$.

Negative predictive value = $8 \times 100/8 + 8 = 50 \%$.

Table 2 Data analysis of cases with deaf mutism

OAE abnormality	No. of ears with disease	No. of ears without disease	Total
OAE test positive	216	0	216
OAE test negative	8	0	8
Total	224	0	224 (no. of ears)

Table 3 Data analysis of cases with CSOM

OAE abnormality	No. of ears with disease	No. of ears without disease	Total
OAE test positive	32	4	36
OAE test negative	8	20	28
Total	40	24	64

Table 4 Data analysis of cases with otosclerosis

OAE abnormality	No. of ears with disease	No. of ears without disease	Total
OAE test positive	72	8	80
OAE test negative	8	8	16
Total	80	16	96(no. of ears)

TEOAE with 90 % sensitivity and positive predictive value is a good diagnostic tool for otosclerosis. Early diagnosis is the key in the management of this disorder.

Data analysis of cases with presbycusis (Tables 5)

Sensitivity = $72 \times 100/72 + 8 = 90 \%$.

Specificity = $4 \times 100/4 + 4 = 50.00 \%$.

Positive predictive value = $72 \times 100/72 + 4 = 94.73 \%$.

Negative predictive value = $4 \times 100/4 + 8 = 33.3 \%$.

Presbycusis is a disorder of the internal ear. Patients with this disorder need rehabilitation with a hearing aid. TEOAE test provides necessary information for the selection and tuning of the hearing aid with frequency specifications. In the diagnosis of hearing defect in patients with presbycusis, the high indices (sensitivity of 90 % and positive predictive value of 94.73 %) suggests the usefulness of TEOAE test as a screening technique for presbycusis.

Data analysis of cases with vertigo (Tables 6)

Sensitivity = $36 \times 100/36 + 8 = 81.81 \%$.

Specificity = $24 \times 100/24 + 12 = 66.66 \%$.

Positive predictive value = $36 \times 100/36 + 12 = 75 \%$.

Negative predictive value = $24 \times 100/24 + 8 = 75 \%$.

Disorders of labyrinth are usually associated with hearing defect as well. TEOAE test provides a good tool in

Table 5 Data analysis of cases with presbycusis

OAE abnormality	No. of ears with disease	No. of ears without disease	Total
OAE test positive	72	4	76
OAE test negative	8	4	12
Total	80	8	88

Table 6 Data analysis of cases with vertigo

OAE abnormality	No. of ears with disease	No. of ears without disease	Total
OAE test positive	36	12	48
OAE test negative	8	24	32
Total	44	36	80

the diagnosis of such cases (as sensitivity of vertigo is 81.81 % and positive predictive value is 75 %).

Data Analysis of Cases with Tinnitus (40 Ears)

Sensitivity = $24 \times 100/24 + 4 = 85.71 \%$.

Specificity = $8 \times 100/8 + 4 = 66.66 \%$.

Positive predictive value = $24 \times 100/24 + 4 = 85.7 \%$.

Negative predictive value = $8 \times 100/8 + 4 = 66.6 \%$.

The high sensitivity and positive predictive values indicates that TEOAE test can be use as diagnostic tool for tinnitus of inner ear origin.

Data Analysis of Normal Controls (72 Ears)

Out of 72 ears (all ears were without disease), 68 were OAE test negative and 4 was OAE test positive.

Specificity = $68 \times 100/68 + 4 = 94.44\%$

Sensitivity could not be calculated because the group comprised of normal healthy controls. Specificity is an important index for the screening test as far as screening is done among a group comprising a majority of normal individuals were false positive results would adversely affect the credibility of a screening test. A high specificity of 94.44 indicates the suitability of TEOAE test for this purpose.

Composite analysis of all study groups (800 ears)

Sensitivity = $528/528 + 72 \times 100 = 88 \%$.

Specificity = $136/136 + 64 \times 100 = 68 \%$.

Positive predictive value = $528 \times 100/528 + 64 = 89.18 \%$.

Negative predict value = $136/136 + 72 = 65.38 \%$.

The sensitivity and positive predictive value for the composite group comprising all study groups were 88 and 89.18 % respectively. As the study groups were categorized in such a manner that it comprised of all common etiological groups, the high indices are suggestive of the feasibility of TEOAE testing as a suitable screening test for hearing loss.

Discussion

The prevalence of hearing disorders as per various studies is [1] WHO 1967, 0.1 %; [2] BIRREL.J.F. 1986, 0.12 %; [3] FRASER.G.R. 1987, 0.1 % [6], and in present study prevalence is 0.412 %. OAEs provide information related to the function of the outer hair cells (OHC). The present of OAE tells us that the conductive mechanism of the ear is

functioning properly thus it can give information regarding otitis media with effusion, CSOM, otosclerosis. This includes proper forward and reverse transmission, no blockage of the external auditory canal, normal tympanic membrane movement, and a functioning impedance matching system [4, 8]. Physiology of OAE is that changes in voltage across the plasma membrane lead to OHC length changes (shortening and lengthening), which are called electromotility. The electro motility of the OHCs has a feedback effect on the basilar membrane, causing it to vibrate. Therefore, the electromotility of the OHCs is thought to be the mechanism which underlies OAEs [2, 7]. Using OAEs to monitor ototoxic medications is logical. Ototoxic drugs exert their effect on OHC function (although not solely on OHCs), and OAEs are OHC dependent [1]. During ototoxicity monitoring, the patient should have OAE testing completed at baseline and before each administration of the ototoxic medication. A change of 2.4 dB was reported as a significant decrease [9], OAEs are a good clinical choice in monitoring for ototoxicity because they are quick. Because they can show a change in cochlear function before it appears on the audiogram, further testing can be avoided unless OAE testing suggests a need. Probably the most common use of OAEs in the diagnosis of retrocochlear pathologies is in the diagnosis of auditory neuropathy (also called auditory dysynchrony or auditory neuropathy spectrum disorder) (ANSD) other possible uses are in diagnosis of deaf mutism, presbycusis, vertigo, and tinnitus [5]. In auditory neuropathy OAEs is preserved but this does not mean this is normal. Thus it is a false positive finding (Table 7).

High indices of observations suggesting feasibility of TEOAE testing as a suitable screening test for otitis media with effusion, deaf mutism, otosclerosis, presbycusis, vertigo, tinnitus and CSOM.

The use of OAEs in the assessment of patients with Meniere's disease has been well documented [11]. In patients with tinnitus, OAEs are not easily detectable or are abnormal at the tinnitus frequency region, even in patients

with normal hearing. Perhaps the most promising area for the use of OAEs with patients with tinnitus is in the area of tinnitus monitoring. Recording OAEs before, during, and after tinnitus retraining therapy may show objective improvements in addition to subjective reports [3].

Programming of hearing aid-the concept behind this lies in the ability of OAEs to identify regions of the cochlea with damage, which can assist in programming a hearing aid. Absent OAEs in conjunction with audiometric thresholds of 70 dB HL or greater can be an indicator of a cochlear dead region, which in turn can influence the hearing aid selection and programming [4].

OAEs as acoustic fingerprints-OAEs can be used as biometric technology, like fingerprints, to identify individuals. Although OAEs in the cochlea may all be alike, each person's unique middle ear system and external ear change the characteristics of the OAE. Thus, an individual's OAE may be used as an "acoustic fingerprint" to unlock that person's phone or iPod [10].

OAEs and intraoperative monitoring-OAEs can be used to monitor the function of the nVIII in acoustic neuroma resection surgery. They can also be used to assess hearing in the operating room following grommet tube insertion; however, their absence in these situations may be due to reasons not related to cochlear function (such as edema, blood, mucosa, etc. in the middle or outer ear [4].

OAEs in musicians-OAEs can provide an early and reliable warning sign of cochlear dysfunction due to noise/music exposure before any problem is evident on the audiogram. For music professionals, maintenance of hearing not only improves quality of life, but it can preserve their employment and livelihood [5].

In our study eight ears of deaf mutism having false negative results on OAE testing so they passed the screening OAE testing. In present study high sensitivity 81.81 % (vertigo), 85.71 % (tinnitus) and high specificity 66.66 % (vertigo), 66.66 % (tinnitus) indicates that OAEs have a potential role in diagnosis of vertigo and tinnitus of inner ear origin. But it depends on the level of hearing threshold.

Table 7 showing different parameters by OAE in following disorders

Disease	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
1. Otitis media with effusion	72	77.77	90	50
2. Deaf mutism	96.42		100	
3. Otosclerosis	90	50	90	50
4. Presbycusis	90	50	94.73	33.33
5. Vertigo	81.81	66.66	75	75
6. Tinnitus	85.71	66.66	85.7	66.6
7. CSOM	80	83.3	89	71.4

Conclusions

From this study we conclude that

1. Hearing loss is a significant health problem in our society with prevalence of 0.412 % among hospital attending population. This problem needs meticulous screening, proper treatment, and suitable rehabilitation, to reduce disease burden on the society.
2. Transient Evoked Otoacoustic Emission testing is a reliable, simple and cost effective screening technique for hearing loss with sensitivity varying from 72 to 96.42 % among the study groups and 88 % in composite group comprising all study groups.
3. The major causes of hearing loss among the study group were deaf mutism, otitis media with effusion, presbycusis, and chronic otitis media. Study points to the fact that majority of the cases were having a treatable cause.
4. The causes for false positive results included wax in the external auditory canal, high ambient noise, and faulty calibration of the equipment.
5. As part of the audiological diagnostic test battery, OAEs can contribute to differential audiological diagnosis, they can be used to monitor the effects of treatment and they can be helpful in the selection of hearing aids and of surgical options.

Conflict of interest None.

References

1. Durrant JD, Campbell K et al (2009) Position statement and clinical practice guideline: ototoxicity monitoring. *Am Acad Audiol* 1–25
2. Brownell WE (1990) Outer hair cell electromotility and otoacoustic emissions. *Ear Hear* 11(2):82–92
3. Ceranic BJ, Prasher DK, Luxon LM (1998) Presence of tinnitus indicated by variable spontaneous otoacoustic emissions. *Audiol Neurotol* 3(5):332–344
4. Gorga MP, Neely ST, Ohlrich B, Hoover B, Redner J (1997) From laboratory to clinic: a large scale study of distortion product otoacoustic emissions in ears with normal hearing and ears with hearing loss. *Ear Hear* 18:440–455
5. Hall J (2000) Handbook of otoacoustic emissions. Singular Publishing Group Thomson Learning, New York
6. Kemp DT (1978) Stimulated acoustic emissions from within the human auditory system. *J Acoust Soc Am* 64:1386–1391
7. Shehata WE, Brownell WE, Dieler R (1991) Effects of salicylate on shape, electromotility and membrane characteristics of isolated outer hair cells from guinea pig cochlea. *Acta Otolaryngol* 111(3):707–718
8. Stach B (2003) Comprehensive dictionary of audiology illustrated, 2nd edn. Thomson Delmar Learning, New York
9. Stavroulaki P, Vossinakis IC, Dinopoulou D, Doudounakis S, Adamopoulos G, Apostolopoulos N (2002) Otoacoustic emissions for monitoring aminoglycoside-induced ototoxicity in children with cystic fibrosis. *Arch Otolaryngol Head Neck Surg* 128:150–155
10. Swabey, M.A., Beeby, S. P., Brown, A.D., Chad, J. (2004). Using otoacoustic emissions as a biometric
11. Van Huffelen WM, Mateijsen NJM, Wit HP (1998) Classification of patients with Meniere's disease using otoacoustic emissions. *Audiol Neuro-Otol* 3:419–430