

# Sensitivity and Specificity of Portable Transient Otoacoustic Emission (TEOAE) in Newborn Hearing Screening

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## Summary

Early identification and management of hearing impairment is very valuable. The gold standard measurement of hearing loss is by brainstem evoked response (BSER). This prospective study was conducted in Hospital University Kebangsaan Malaysia (HUKM) to determine the sensitivity and specificity of transient evoked otoacoustic emission (TEOAE) as a screening tool for hearing impairment from February 1999 to February 2000. One hundred and thirty-three newborns from postnatal ward and seventy-eight newborns from neonatal intensive care unit (NICU) were screened for possible hearing loss using portable TEOAE. This study showed that TEOAE is a very sensitive but moderately specific screening tool.

**Key Words:** Transient otoacoustic emission, Brainstem-evoked response, Hearing screening, Hearing loss

## Introduction

Congenital bilateral permanent childhood hearing impairment of 40 dB or more is about 1.1 per 1000 life birth in Europe<sup>1</sup>. Other studies showed the prevalence of unilateral / bilateral mild to profound hearing loss to be 1.5 to 6 per 1000 life birth<sup>2,3,4,5</sup>. The prevalence of unilateral/bilateral mild to profound sensorineural hearing loss is estimated to be 1.5 to 6 per 1000<sup>6</sup>. The goal of a hearing screening program is for early detection of hearing loss so that a rehabilitation program can be started immediately<sup>7,8</sup>. Research done by Yoshinaga Itano indicates that identification followed by intervention before 6 months of age results in essentially normal language at age 3 years<sup>9</sup>.

The average age of identification of congenital hearing loss in United States (US) in 1993 according to national Institute of health was about 3 years<sup>10</sup>. Erenberg et al.,

reported that the average age of detection of significant hearing loss is fourteen months<sup>11</sup>. In New Zealand in 1996 the mean age detection of hearing impairment was at 26 months<sup>12</sup>.

Anthony Gilbert reported that the prevalence of hearing impairment among high-risk infants was 26.4% at 3 months and 18.8% at 6 months<sup>13</sup>. Other studies showed as many as half of children with bilateral severe to profound hearing losses never exhibited any of the high-risk factor<sup>1,14</sup>. Such targeted screening, even if it were perfectly implemented, would miss at least half of the children with bilateral hearing loss<sup>15</sup>. Therefore it is advisable to screen all live birth neonates.

One promising technique for newborn hearing screening is the measurement of otoacoustic emissions (OAEs), first described by Kemp<sup>16</sup>. Kemp's works showed that, if the cochlea is functioning normally, the

This article was accepted: 14 July 2004

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outer hair cell simultaneously emit sound or an 'echo' back through the middle ear. This echo or otoacoustic emission (OAE) can be recorded in the external ear canal by a small, sensitive microphone connected to microcomputer<sup>17</sup>.

This study was planned to determine the sensitivity and the specificity of the new screening tool for hearing loss compared to the "gold standard".

**Materials and Methods**

This is a prospective study from February 1999 until February 2000. The population of the study comprises of infants from postnatal ward and Neonatal Intensive Care Unit (NICU) in Hospital Universiti Kebangsaan Malaysia (HUKM). One hundred and thirty-three newborns from postnatal ward and seventy-eight newborns from NICU were screened for hearing loss using portable TOAE.

In the postnatal ward, TOAE test were carried out at the bedside or inside the nursery room within 24 hours of life. In the NICU, the test was conducted by the bedside or inside the incubator. The test was performed before the newborn was discharged from

the NICU. After otoscopic examination, the probe was inserted into the external ear canal and adjusted. If the TEOAE could not be recorded or gave 'fail' result despite the absence of ambient noise in the room and infant baby being quiet, a second attempt for TOAE testing was performed immediately after the first attempt.

Newborns who did not meet the pass criteria at the second attempt, were given an appointment to Otorhinolaryngology (ORL) clinic at the age 2 months ± 2 weeks. Those infants who failed second stage will given follow up at the age 6 months ± 2 weeks for repeat BSER and behavioral test.

**Results**

The majority of the newborns in postnatal ward and NICU were Malays. One hundred thirty-three patients from postnatal ward were tested at the first stage, 96 patients (72.2%) passed and 37 patients (27.8%) failed the screening test. During the second stage screening 35 patients passed (Appendix 1). Seventy-eight patients from NICU were tested using TEOAE, 50 patients (64.1%) passed and 28 patients (35.9%) failed during first stage screening (Appendix II).

BSER AT 8/52			BSER AT 8/52			BSER AT 6/12		
	Fail	Pass		Fail	Pass		Fail	Pass
Fail OAE	6	29	Fail OAE	5	10	Fail OAE	4	8
Pass OAE	1	9	Pass OAE	0	19	Pass OAE	0	17
Sensitivity = 85.7% Specificity = 39.6%			Sensitivity = 100.0% Specificity = 65.5%			Sensitivity = 100.0% Specificity = 68.0%		

**Fig 1 : Sensitivity and specificity of TEOAE compared with BESR result for patients from postnatal ward**

Figure I showed the relationship between TEOAE and BSER test at initial screening, at the age of 2 months ± 2 weeks and at 6 months. A comparison of re-screen TEOAE and BSER of 6 months shows the sensitivity (the percentage of actual hearing impaired babies who received 'Fail' was 100.0%) and the specificity (the percentage of normal hearing infant who received 'Pass' was 68.0%).

BSER at 8/52			BSER at 8/52			BSER at 6/12		
	Fail	Pass		Fail	Pass		Fail	Pass
Fail OAE	7	18	Fail OAE	6	6	Fail OAE	5	7
Pass OAE	1	11	Pass OAE	0	24	Pass OAE	0	20
Sensitivity = 87.5% Specificity = 37.9%			Sensitivity = 100.0% Specificity = 80%			Sensitivity = 100.0% Specificity = 74.1%		

**Fig II : Sensitivity and specificity of TEOAE compared with BSER results among patients in intensive care unit.**

Figure II showed the relationship between TEOAE and BSER test at initial screening, at the age of 2 months and at 6 months. The sensitivity compared between re-screen TEOAE and BSER at 6 months was 100.00% but the specificity was only 74.1%.

**Discussion**

TEOAE has proved to be successful in newborn hearing screening because it is sensitive to lesion in the cochlea<sup>18,19</sup>. However TEOAE requires normal middle ear function<sup>20</sup>. Retro-cochlear or central auditory lesion will not affect the TEOAE result. The incidence of acoustic nerve or brainstem involvement is rare in the general newborn population<sup>19</sup>.

There are two important issues for a screening test; effectiveness and efficiency. Screening is effective if the number of false negative is small or the sensitivity approaches 100%<sup>21</sup>. A screening is efficient if the number of false positives is small or the specificity approaches 100%<sup>21</sup>.

The result of the TEOAE screening performed by White et al, on 1850 neonates showed a sensitivity of 100% and a specificity of 73%<sup>15</sup>. According to that study TEOAE was moderately, specific but very sensitive. In other words, TEOAE did not have any false negative. False negative is the proportion of neonates/patients who pass screening test even though they have hearing loss. False negative is equaled to 1 – sensitivity. Based

on that study, TEOAE has false positive. False positive is the proportion of neonates who failed the screening test even though they did not have any hearing loss. The false positive equals 1- specificity (1-0.73) = 0.23 or 23%<sup>15</sup>.

Bantock and Croxson conducted TEOAE screening in 700 neonates with risk factors for hearing loss and on 1492 on neonates without any risk factors<sup>20</sup>. They found in both groups the sensitivity was 100%. The specificity in both groups was 94% and 91% respectively. For the second stage-screening test about six months later, the sensitivity remained 100% and specificity improved to 99.3% in a group with no risk factors for hearing loss<sup>20</sup>.

In this study, the sensitivity of portable TEOAE for postnatal ward patients was about 85.7%, 100.0% and 100.0% at first stage, second stage and third stage respectively. In other words there were about 14.3%, 0% and 0% of false negative. The specificity of this TEOAE for postnatal ward patients was 36.9%, 65.5% and 68.0% at first, second and third stage respectively.

The sensitivity of NICU patient was 87%, 100.0% and 100.0% at the first second, third stage respectively. Whereas the specificity of TEOAE was 37.9%, 80.0% and 74.1% at first, second and third stage respectively. These showed that TEOAE has moderate specificity. At the third stage, it has a false positive result of 32% and 25.9% for postnatal ward and NICU respectively.

There are several factors that affect the sensitivity and specificity. The factors includes: the level of noise present during the OAE recording, the age of patients, probe fitting, state of the infant, presence of debris/vernix in the EAC or middle ear effusion.

### Recommendation

The screening test needs to include long term follow up, bigger sample size and proper data management system. The timing of the test need be after 24 hours after lower caesarian section and vaginal delivery or before discharge for NICU patients.

Mason et al decided to put forward information and guidelines regarding the automated auditory brain response (AABR) as screening tool<sup>23</sup>. AABR has high sensitivity, high specificity, simple and quick test procedure. It also has viability of recorded waveforms for checking and for audit purposes<sup>23</sup>.

### Conclusion

In this study, TEOAE is sensitive and moderately specific screening tool for hearing impairment as compared to the other studies<sup>21,22</sup>. At second and third stage screening test, the sensitivity was 100% for both groups. Whereas the specificity was 68% and 74.1% for post natal and NICU patients respectively. Although the test is quick, noninvasive, easy and does not require skilled personnel to perform, further study is needed to improve the specificity. We would like to stress again that the timing and the stability of the probe in the external ear canal are very important to reduce false positive results. Other measures such as the room where the test is performed, the middle ear status and the size of the probe are also important.

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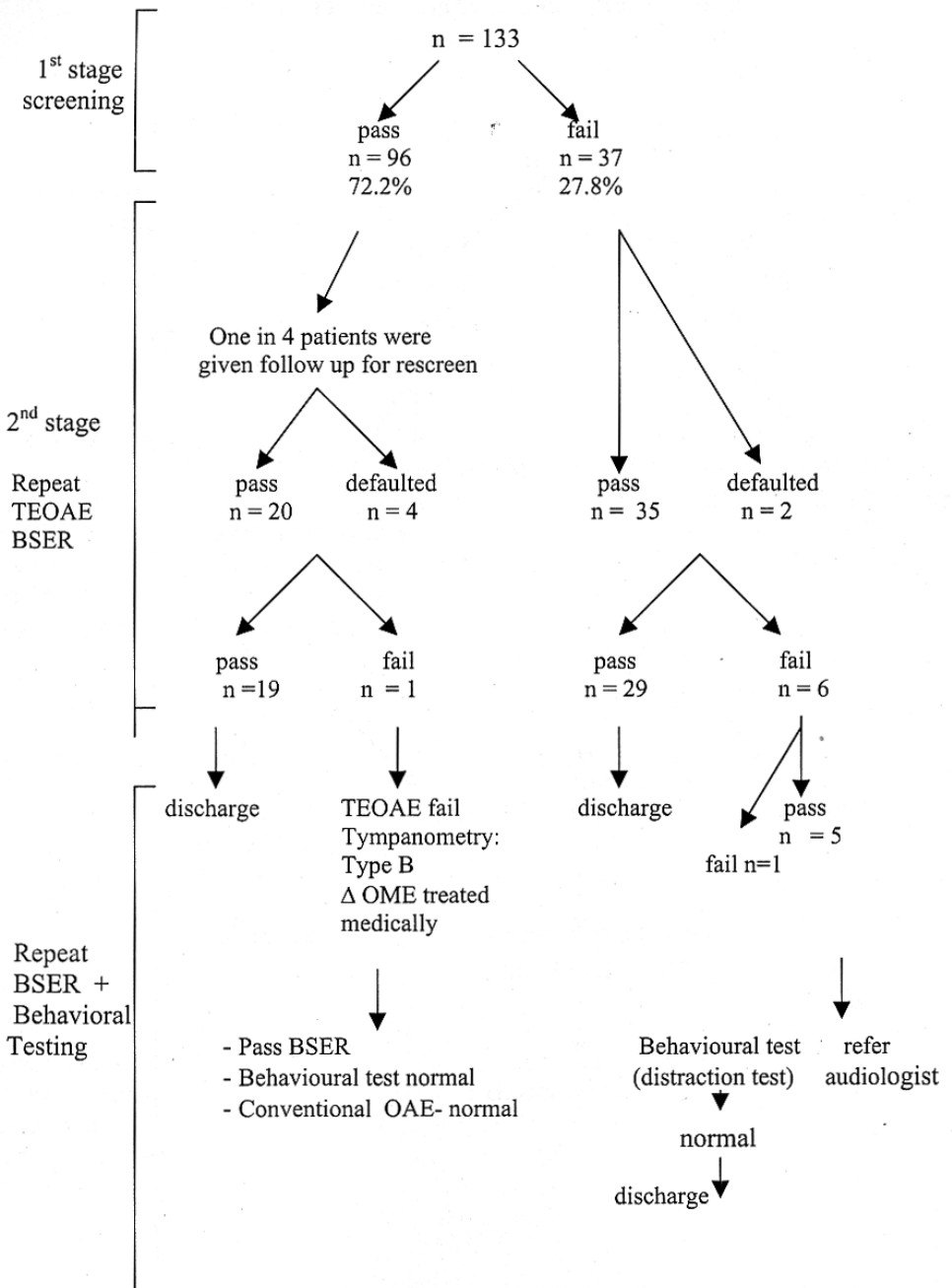
## References

1. Davis A, Bradford J, Wilson I, Ramkalawan T, Forshew M, Wright S. A critical review of the role of neonatal hearing screening in the detection of congenital hearing impairment. *Health Technol. Assess* 1997; 1: 1-17.
2. Johnson MJ, Baggie P, Elberling C. Evoked otoacoustic emission from the human ear finding in neonates. *Scandinavian Audiology* 1983; 12: 17-24.
3. Schulma, GC, Galambas R. Brainstem evoked response audiometry in newborn hearing screening. *Arch-otol* 1979; 1-5: 86-90.
4. Watkins P, Baldwin M, McEnergy G. Neonatal at risk screening and the identification of deafness. *Arch Dis child* 1991; 66: 1130-5.
5. Schein JD, Duk MT. The deaf population at Auditory screening of infants in United States. *National association of the deaf*, 1974; 23: 34-9.
6. Collet L, Levy V, Vevillet E, Morgan TA. Click-evoked otoacoustic emissions and hearing threshold in sensorineural hearing loss *Pediatric* 1993; 14: 141-9.
7. Greenberg MT. Family stress and child competence: the effects of early intervention for family with deaf infants. *Am and Deaf* 1983; 128: 407-11.
8. Strong DJ, Clark TC, Walden BE. The relationship of hearing loss severity to demographic, age, treatment and intervention effectiveness variables. *Ear & Hearing* 1984; 15: 126-37.
9. Yoshinaga-Itano, C. Efficacy of early identification and early intervention. *Seminar in Hearing* 1995; 16: 115-20.
10. National Institutes of Health. Early identification of hearing impairment in infants and younger children. Maryland, USA: National Institutes of Health, 1993; 11 (1): 1-24.

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11. Erenberg A, Lemon J, Sia Calvin, Tunkel D, Ziring P, Adam M, Holstrum Jo McPherson M, Paneth M, Strickland BN. Newborn and Infant Hearing: Detection and Intervention. *Pediatric* 1999; 103: 527-30.
12. Davis WK, Anne G, Peter RT, Suzanne, CP. Influence of acquisition parameters on the measurements of clock evoked otoacoustic emissions in neonates in hospital environment. *Audiology* 1996; 35: 143-57.
13. Anthony Gilbert – Comparison of transient evoked otoacoustic emission (TOAE) to brain stem evoked response (BSER) for screening of hearing loss in high-risk infant. Dissertation submitted in partial fulfillment for the degree of Master of Surgery in Otorhinolaryngology, Head and Neck. Faculty of Medicine Universiti Kebangsaan Malaysia 1997.
14. Mason JA, Hermann KR. Universal infant hearing screening by automated auditory brainstem response measurement. *Pediatrics* 1998; 101: 221-8.
15. White KR, Vohr BR, Behrens R. Universal newborn hearing screening using transient evoked otoacoustic emission: results of the Rhode Island hearing assessment project. *Seminar in Hearing* 1993; 14: 18-29.
16. Kemp PT. Stimulated acoustic emissions from the human auditory system. *J. Acous Scoc. Am* 1978; 64: 1386-91.
17. Finitzo T, Albright K, O'Ne. J. The newborn with hearing loss. Detection in the nursery. *Pediatrics* 1998; 102(b): 1452-60.
18. Francois M, Lancorre L, Huy ET, Marcy P. Hearing impairment in infants after meningitis, detection by transient otoacoustic emission. *J. Pediatric* 1997; 130: 712-17.
19. Cox CL. Otoacoustic emission as screening tool for sensorineural hearing loss. *J. Pediatric* 1997; 130: 685-86.
20. Bantock H.M, Croxson, S. Universal hearing screening using transient otoacoustic emissions in a community health clinic. *Arch Dis Child* 1998; 78: 249-52.
21. Brass D. and Kemp DT. Quantitative assessment of methods for the detection of otoacoustic emissions. *Ear and Hearing* 1994; 15: 378-89.
22. Vohr BR, White KR, Maxon AB, Johnson MJ. Factors affecting the interpretation of transient evoked otoacoustic emission result in neonatal hearing screening. *Seminar in Hearing* 1993; 14: 57-72.
23. Mason S, Eliot C, Parker D, et al,. Neonatal Hearing Screening and Assessment, Automated Auditory Brainstem Response. Information and guidelines for screening hearing in babies 2000.

### Appendix I Results of newborns hearing screening from postnatal ward using TEOAE



**Appendix II**  
**Results of newborns hearing screening using transient evoked otoacoustic emission from neonatal intensive care unit HUKM**

