Acta Oto-Laryngologica, 2007; 127: 384–388

informa
healthcare

ORIGINAL ARTICLE

Correlation of hearing screening with developmental outcomes in infants over a 2-year period

CHARLOTTE CHIONG[1], ENRIQUE OSTREA JR.[2,3], ALEXIS REYES[3], ERASMO GONZALO LLANES[1], MA. ESTERLITA UY[3] & ABNER CHAN[1]

[1]*Department of Otorhinolaryngology, College of Medicine – Philippine General Hospital and Philippine National Ear Institute, National Institutes of Health, University of the Philippines, Manila, Philippines,* [2]*Department of Pediatrics (Neonatal Medicine), School of Medicine, Wayne State University, Detroit, MI, USA and* [3]*Department of Pediatrics (Developmental Pediatrics), Institute of Child Health and Development, National Institutes of Health, University of the Philippines, Manila, Philippines*

Abstract
Conclusion: Evoked otoacoustic emission (OAE) and auditory brainstem response (ABR) results for hearing screening among infants have good concordance. However, good correlation with the Griffiths Developmental Scales remains to be desired. *Objective:* To correlate hearing screening outcomes of a cohort of infants with developmental outcomes at 6 and 12 months. *Subjects and methods:* A cohort of pregnant women was identified in several communities in a rural area (Bulacan province) from April 2002 to February 2003 as part of a population-based study determining maternal exposure to pollutants and infant outcomes, with a total follow-up of 2 years. Pregnant mothers were identified and followed up until delivery at a secondary, provincial hospital. Hearing screening was performed with OAEs and ABR. Mental development of infants was assessed at 6 and 12 months using Griffiths Mental Developmental Scales – locomotor, personal-social, hearing and speech, hand and eye coordination, performance tests. *Results:* Among the 1086 babies recruited, there were 724 with hearing assessment. Of these 724 babies, 565 had both OAE testing and ABR. Overall in 1130 ears, OAE and ABR testing showed an observed agreement of 99%, agreement due to chance of 96%, and kappa agreement of 79% ($p = 0.00$) in diagnosing bilateral hearing losses. OAEs had a sensitivity of 86.4% (95% CI 64–96.4%) and a specificity of 99.4% (95% CI 98.6–99.7%). At the end of the study, there were 708/724 (97.8%) infants with normal hearing, 7/724 (1.0%) with unilateral hearing loss, 8/724 (1.1%) with bilateral mild hearing loss, and 1/724 (0.1%) with bilateral profound hearing loss, who demonstrated consistent mental delay throughout. Follow-up rates for developmental examinations at 6 and 12 months were 98% and 81.25%, respectively. In these groups, there were 8 (1%) infants at 6 months and 18 (2.4%) at 12 months with developmental delay (Griffiths Mental Developmental Scales).

Keywords: *Hearing screening, infants, developmental outcomes*

Introduction

The advent of new and affordable technology over the past years has helped to jumpstart newborn hearing screening programs worldwide, even in developing countries. Awareness among health practitioners and the public of the importance of hearing have increased 10-fold because of these concerted efforts to identify babies with hearing loss as early as possible, and in turn, provide early treatment and rehabilitation.

In our setting over the past 5 years, a number of hospitals have carried out newborn hearing screening programs, the majority of which were instituted in public and private tertiary hospitals in the nation's capital. However, these applied varied protocols and in the majority follow-through refer rates have been unreported but generally not good. Diagnostic technologies like otoacoustic emissions (OAEs) and auditory brainstem response (ABR) may still be relatively costly, more so with hearing rehabilitation

Correspondence: Erasmo Gonzalo Llanes, Department of Otorhinolaryngology, College of Medicine – Philippine General Hospital and Philippine National Ear Institute, National Institutes of Health, University of the Philippines, Manila, Philippines. E-mail: erisllanes@yahoo.com

(Received 13 September 2006; accepted 20 October 2006)

ISSN 0001-6489 print/ISSN 1651-2551 online
DOI: 10.1080/00016480601075431

whether with hearing aids and/or cochlear implantation. However, bringing these technologies as well as their benefits to the community where the majority of underprivileged patients are to be found would really be more meaningful in our case, where only 38% of births are within health facilities [1].

Previous reports [2,3] have documented our experience in starting hearing screening at a tertiary hospital, with both OAEs and ABR at the neonatal intensive care unit, where there was a 29% bilateral 'refer' rate but on follow-up a mere 10% to special populations referred to our Ear Unit for hearing assessment. It remains to be seen whether hearing screening with OAE and ABR in a community-based study will be as accurate. Moreover, correlation with accepted developmental instruments may be advantageous in order to assess the impact of hearing loss (if any) on development during the early years of life. In this paper, we present our experience in hearing screening of babies at the community level using OAE and ABR. Results of developmental assessment of hearing and speech were then correlated with hearing screening results.

Subjects and methods

A cohort of pregnant women was identified in several communities in a rural area (Bulacan province) from April 2002 to February 2005 as part of a population-based study determining maternal exposure to pollutants and infant outcomes, with a total follow-up of 2 years. Pregnant mothers were identified and followed up until delivery at a secondary, provincial hospital. Newborns underwent hearing screening with OAE (Welch Allyn® Audiopath EOAE Screener 29230) and ABR (Interacoustics EP15). Mental development of infants was assessed by a team of developmental pediatricians at 6 and 12 months using the Griffiths Mental Developmental Scales – locomotor, personal-social, hearing and speech, hand and eye coordination, performance tests [4]. The Griffiths Mental Developmental Scale is a test instrument administered by pediatricians from birth until 8 years of age, and measures motor maturity and development, ability to cope with routine situations in everyday living, auditory and speech functions, hand and finger motor mobility and eye and hand coordination, body consciousness, physical activity, and memory.

Results

There were 450 (54.4%) males, 375 (45.4%) females, and 2 (0.2%) ambiguous babies. Among the 1086 babies recruited, 724 underwent hearing assessment. Of these 724 babies, 565 had both OAE and ABR testing. Overall in 1130 ears, OAE and ABR testing showed an observed agreement of 99%, agreement due to chance of 96%, and kappa agreement of 80% ($p = 0.00$) in diagnosing bilateral hearing losses. OAEs had a sensitivity of 86.4% (95% CI 64–96.4%) and a specificity of 99.4% (95% CI 98.6–99.7%) (Table I–III). At the end of the study, based on the ABR threshold results there were 708/724 (97.8%) infants with normal hearing, 7/724 (1%) with unilateral mild hearing loss, 8/724 (1%) with bilateral mild hearing loss, and 1/724 (0.1%) with bilateral profound hearing loss, who demonstrated consistent mental delay throughout. Thus, the total prevalence of hearing loss documented was 2.2%.

In all, 84% of babies were screened during the first 6 months of life, with 476 (77%) from 0 to 3 months and 43 (7%) from 4 to 6 months, and a further 6% from 6 to 9 months.

Follow-up rates for developmental examinations at 6 and 12 months were 98% and 81.25%, respectively. In these groups, there were 8 (1%) infants at 6 months and 18 (2.4%) at 12 months with developmental delay (Griffiths Mental Developmental Scales) [5].

There were 15 babies with hearing loss identified through ABR thresholds (Table III) with 1 baby having bilateral profound hearing loss. In this group, there were 3/22 (14%) ears of babies with

Table I. Concordance of otoacoustic emissions (OAEs) and auditory brainstem response (ABR) among 565 children, right ears.

	Auditory brainstem response		
Otoacoustic emissions	>40 dB	≤40 dB	Total
Refer	11	2	13
Pass	0	552	552
Total	11	554	565

Observed agreement = 0.99; sensitivity = 100% (67.9–100); agreement due to chance = 0.96; specificity = 99.6% (98.6–99.9); kappa = 0.91, $p = 0.00$; positive predictive value = 84.6% (53.7–97.3); negative predictive value = 100% (99.1–100).

Table II. Concordance of otoacoustic emissions (OAEs) and auditory brainstem response (ABR) among 565 children, left ears.

	Auditory brainstem response		
Otoacoustic emissions	>40 dB	≤40 dB	Total
Refer	8	5	13
Pass	3	549	552
Total	11	554	565

Observed agreement = 0.99; sensitivity = 72.7% (39.3–92.7); agreement due to chance = 0.96; specificity = 99.1% (97.8–99.7); kappa = 0.66; $p = 0.00$; positive predictive value = 61.5% (32.3–84.9); negative predictive value = 99.5% (98.3–99.9).

Table III. Concordance of otoacoustic emissions (OAEs) and auditory brainstem response (ABR) among 1130 ears, right and left.

Otoacoustic emissions	Auditory brainstem response >40 dB	≤40 dB	Total
Refer	19	7	26
Pass	3	1101	1104
Total	22	1108	1130

Observed agreement = 0.99; sensitivity = 86.4% (64–96.4); agreement due to chance = 0.96; specificity = 99.4% (98.6–99.7); kappa = 0.88; $p = 0.00$; positive predictive value = 73.1% (51.9–87.6); negative predictive value = 99.7% (99.1–99.9).

ABR thresholds >40 dB HL, with 'pass' responses in the OAE testing (false negative). Three of seven with unilateral mild hearing loss and two of five with bilateral mild hearing loss had low development scores, while the baby with bilateral profound hearing loss had consistently poor development scores. Correlation of the different subdomains with hearing impairment did not yield much in the way of conclusions. However, correlation of the hearing screening results with the subdomain of speech and hearing showed good correlation.

The results of the study are summarized in Tables IV–IX .

Discussion

Community hearing screening in a population-based study is an ideal methodology to determine the efficiency of a screening program. Data gathered, as well as logistics and other resources can be identified, which are valuable in formulating the work plan. It is hoped that this undertaking will be a prelude to our efforts to establish a national primary care newborn hearing screening program.

Our results showing bilateral profound hearing loss of 1 per 724 babies in a general population are still slightly higher than the usual 1 per 1000 proportional rate often reported. It is interesting to note that even with active case identification, where the staff go house-to-house, in spite of the acceptable coverage rate, there are still a number of babies that were screened after 6 months. The value of universal hearing screening has been demonstrated in a recent report [6] of an 8-year follow-up of a controlled trial on universal newborn hearing screening which increased the proportion of all true cases of permanent childhood hearing impairment referred before the age of 6 months. Identification and referrals to an audiology unit have been

Table IV. Distribution of patients according to age screened.

Age group (months)	Frequency	%
1–3	476	77.24
4–6	43	6.97
7–9	89	14.44
10–12	5	0.80
>12	3	0.38
Total	616	100.0

Table V. Distribution of patients with abnormal hearing tests.

Patient	Otoacoustic emissions		ABR thresholds	
Unilateral mild	Right	Left	Right	Left
1	Refer	Pass	50	40
2	Pass	Pass	20	50
3	Refer	Refer	50	30
4	Pass	Pass	20	50
5	Pass	Refer	30	50
6	Pass	Refer	40	50
7	Refer	Pass	50	40
Unilateral moderate				
8	Refer	Pass	80	40
Bilateral mild				
9	Refer	Refer	50	60
10	Refer	Refer	50	50
11	Refer	Pass	60	50
12	Refer	Refer	50	50
13	Refer	Refer	50	50
14	Refer	Refer	60	60
Bilateral profound				
15	Refer	Refer	100	100

Table VI. Distribution of hearing/language among patients with abnormal hearing tests.

Patient	Hearing/language			
Unilateral mild	SQ 6 months	Percentile 6 months	SQ 12 months	Percentile 12 months
1	109	71	68	2
2	100	50	71	4
3	105	62	86	19
4	114	81	107	67
5	100	50	83	14
6	100	50	86	19
7	109	71	87	21
Unilateral moderate				
8	109	71	98	45
Bilateral mild				
9	109	71	93	35
10	109	71	94	35
11	105	62	94	35
12	105	62	104	60
13	82	13	83	14
14	91	29	–	–
Bilateral profound				
15	42.3	0.5	68.6	2

Table VII. Distribution of performance scores among patients with abnormal hearing tests.

Patient	Performance			
Unilateral mild	SQ 6 months	Percentile 6 months	SQ 12 months	Percentile 12 months
1	96	40	84	16
2	86	19	84	16
3	91	29	84	16
4	101	52	123	92
5	91	29	91	29
6	106	65	76	7
7	101	52	83	14
Unilateral moderate				
8	62	1	90	27
Bilateral mild				
9	101	52	88	23
10	96	40	98	45
11	91	29	98	45
12	101	52	80	11
13	62	1	80	11
14	86	19	–	–
Bilateral profound				
15	53.84	0.5	90.1	27

improved. In addition, the value of parental education and awareness is emphasized and must be taken into consideration in establishing a community-based universal hearing screening program. Continuing the study to involve more parents and children would be ideal and will yield more information for our purpose.

In the general population, it is expected that the prevalence rate would be lower compared to the hospital or specialized care units, where sick babies are referred and have co-morbid conditions. In this setting, monitoring the mental development through the Griffiths Mental Development Scale (which is an accepted assessment instrument of the mental development of babies up to 2 years old) and correlating with hearing assessments would be interesting. We have seen that in our baby with a bilateral profound hearing loss (ABR thresholds of 100 dB HL) the mental development scores (total general quotient) and in all subscales (locomotor, personal social, hearing and speech, eye–hand coordination, and performance) are lower than the average. Among those with mild hearing loss, whether unilateral or bilateral, at least 40% exhibit lower than average mental development. Whether the lower than average mental development is a result of the hearing impairment remains to be seen with subsequent tests and continuous assessment of these infants. Using the hearing and speech scale, values from this group of patients show that most have lower percentile scores even among those with unilateral mild hearing loss. This implies that while it is important to prioritize bilateral severe hearing losses, we may be underestimating the adverse effect of mild hearing loss among babies in terms of mental development [7]. Assessment at 24 months is therefore desired. Referrals of these babies for rehabilitation may still prove beneficial in the long-term outcome.

Table VIII. Distribution of general quotient scores among patients with abnormal hearing tests.

Patient	General quotient*			
Unilateral mild	6 months		12 months	
1	101.2	Average	78.8	Low average
2	100	Average	95.6	Average
3	99.6	Average	89.8	Low average
4	111.6	High average	107.4	Average
5	105.8	Average	93.6	Average
6	103.8	Average	90	Average
7	106.6	Average	83.4	Low average
Unilateral moderate				
8	90.4	Average	93.4	Average
Bilateral mild				
9	113.4	High Average	84	Low average
10	106.6	Average	100.8	Average
11	102	Average	98.6	Average
12	106.8	Average	97.2	Average
13	76.4	Low	81.6	Low
14	97.2	Average	–	–
Bilateral profound				
15	47.59	Very low	75.64	Low

*Ref. [4].

Table IX. Distribution of general quotient in the Griffiths scale among babies.

Griffiths scale	General quotient	
	6 months	12 months
≤70, abnormal	8 (0.1%)	18 (2.4%)
71–75, borderline	7 (0.9%)	12 (1.6%)
76–89, below average	51 (6.7%)	224 (29.8%)
90–110, average	518 (68.4%)	487 (64.8%)
111–119, above average	147 (19.4%)	10 (1.3%)
>120	26 (3.4%)	0
Total	757	751*

*Six babies were lost to follow-up.

Conclusion

There seems to be a good correlation between newborn hearing screening outcomes and developmental outcomes, especially for babies with hearing impairment. Comparison of these outcomes of babies which had early identification and rehabilitation, even among babies with mild hearing losses, will provide evidence to support the practice of rehabilitating such children as early as possible.

Acknowledgement

This study is supported by the United States National Institutes of Health/National Institute of Child and Development (R01HD039428) and the U.S. Environmental Protection Agency (R829395).

References

[1] Philippine Health Statistics 2002. Department of Health, Manila, Philippines.

[2] Chiong CM, Llanes EGD, Tirona-Remulla AN, Calaquian CME, Reyes-Quintos MRT. Neonatal hearing screening in a neonatal intensive care unit using distortion-product otoacoustic emissions. Acta Otolaryngol (Stockh) 2003;123:215–8.

[3] Llanes EGDV, Chiong CM. Evoked otoacoustic emissions and auditory brainstem responses: concordance in hearing screening among high-risk children. Acta Otolaryngol (Stockh) 2004;124:387–90.

[4] Association for Research in Infant and Child Development. The Griffiths Mental Development Scale (birth – 2 years) manual, 1996 revision. Griffiths R, Huntley M. London: Test Agency Ltd, 1996.

[5] Ivens J, Martin N. A common metric for the Griffiths Scales. Arch Dis Child 2002;87:109–10.

[6] Kennedy C, McCann D, Campbell M, Kimm L, Thomton R. Universal newborn hearing screening for permanent childhood hearing impairment: an 8-year follow-up of a controlled trial. Lancet 2005;366:660–2.

[7] Wake M, Hughes E, Poulakis Z, Collins C, Rickards F. Outcomes of children with mild-profound congenital hearing loss at 7 to 8 years: a population study. Ear Hear 2004;25:1–8.