<table>
<thead>
<tr>
<th><strong>Title</strong></th>
<th>Infant hearing screening: effects of timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Other Contributor(s)</strong></td>
<td>University of Hong Kong.</td>
</tr>
<tr>
<td><strong>Author(s)</strong></td>
<td>Tsui, Wan-yee, Peony; 徐韻怡</td>
</tr>
<tr>
<td><strong>Citation</strong></td>
<td>Tsui, W. P. [徐韻怡]. (2006). Infant hearing screening : effects of timeline. (Thesis). University of Hong Kong, Pokfulam, Hong Kong SAR.</td>
</tr>
<tr>
<td><strong>Issued Date</strong></td>
<td>2006</td>
</tr>
<tr>
<td><strong>URL</strong></td>
<td><a href="http://hdl.handle.net/10722/50070">http://hdl.handle.net/10722/50070</a></td>
</tr>
<tr>
<td><strong>Rights</strong></td>
<td>The author retains all proprietary rights, such as patent rights and the right to use in future works.; This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.</td>
</tr>
</tbody>
</table>
Infant Hearing Screening: Effects of timeline

Peony W.Y. Tsui

Abstract

A two-stage protocol for distortion product otoacoustic emissions (DPOAE) screening, followed by auditory brainstem evoked response (ABR) diagnostic assessment has been adopted by all Maternal and Child Health Centers (MCHCs) in Hong Kong for universal infant hearing screening. The present study hypothesized that administration of the diagnostic assessment after possible clearance of ear debris and resolution of the middle ear effusion would help minimize the ABR refer rate. This study examined the effect of infant age at the time of the testing and the duration of the time lag between the tests on the ABR refer rate. A total of 317 infants referred by the MCHCs for ABR assessment after failing the second DPOAE screening were studied. Infant age of over 50 days at the time of ABR assessment and a time lag between the second DPOAE screening and the ABR assessment of over 20 days were found to contribute to a significant decrease in the ABR refer rate.
Infant Hearing Screening: Effects of timeline

The practice of universal infant hearing screening (UNHS) has been widely adopted since the position statement of the Joint Committee on Infant Hearing (JCIH) in 1994. The JCIH is responsible for making recommendations concerning the early identification of children with, or at-risk for hearing loss, and newborn hearing screening. UNHS was introduced by all Maternal and Child Health Centers (MCHCs) in Hong Kong after a one-year pilot project carried out in 2001 (Chan & Leung, 2004). MCHCs provide a comprehensive range of free health promotion and disease prevention services for all children aged below six, and women of reproductive age. According to Yeung (2001), over 85% of mothers in Hong Kong attend MCHCs.

UNHS allows for the early detection of hearing loss, and thus initiating therapy within the critical period of speech, language and cognitive development, taking advantage of the young child’s auditory plasticity. The JCIH (1995) recommended that all infants with hearing loss should be identified before three months of age, and receive intervention by six months of age. A number of studies have shown that significantly better language development is associated with the identification of hearing loss, followed by comprehensive intervention before six months of age (Sininger, Doyle, & Moore, 1999; Wada, Aiba, & Yamane, 2004; Yoshinaga-Itano, Sedly, Coutler, & Mehl, 1998).

Distortion Product Otoacoustic Emissions (DPOAE)

A two-stage screening protocol with the use of the otoacoustic emission (OAE) technology has been implemented by the MCHCs (Chan & Leung, 2004). OAEs are sounds emitted spontaneously or evoked by means of a stimulus from the cochlea of a healthy ear, which are then measured in the external ear canal. The emission measurement procedure adopted by the MCHCs for UNHS is distortion product otoacoustic emissions (DPOAE). DPOAEs are produced by means of stimulation of the cochlea with two simultaneous pure
tone frequencies, \( f_1 \) and \( f_2 \). The resulting emission is a product of the nonlinear distortion of the basilar membrane and is measured most commonly at the frequency given by the equation \( 2f_1 - f_2 \). The presence of normal DPOAE indicates normal cochlear and middle and external ear function. DPOAE offer an objective, non-invasive, rapid and frequency specific means of assessing the cochlear function (Kemp & Ryan, 1991).

Under the UNHS scheme, DPOAE screening is administered on all infants enrolled in the MCHC programme. For infants who fail the initial DPOAE screening, a second screening is arranged; only babies who fail both initial and second screenings are referred for diagnostic evaluation. Babies who passed either the first or the second DPOAE screening are discharged from the program although a routine hearing screening test is still arranged between six and nine months of age (Chan & Leung, 2004).

**Auditory Brainstem evoked Response (ABR)**

The auditory brainstem evoked response (ABR) assessment is used as the main tool for diagnostic evaluation by the MCHCs. ABR refers to the electrical activity generated by the auditory nerve and the auditory brain stem pathways after the presentation of a click stimulus. By comparing ABR assessment results in infant hearing screening with the behaviorally-confirmed hearing status at four year old, sensitivity of 97-98% and specificity of 96%-100% has been reported (Hyde, Riko, & Malizia, 1990). Reliable ABR can be recorded from infants as young as 30 weeks gestational age. The 1994 JCIH position statement pointed out that ABR has been recommended for newborn hearing assessment for almost 15 years and has been successfully implemented in UNHS. However, ABR is not a test of hearing in the perceptual sense; therefore, infants who failed the ABR assessment would receive follow-up monitoring. Behavioral audiometry would be administrated to complete the pediatric evaluation of hearing sensitivity (Hayes & Northern, 1996).

Behavioral audiometry is a measure of a voluntary or conditioned response to minimally
audible sound, which cannot be reliably obtained from infants younger than six months of age (Spivak & Sokol, 2005).

Critics of high false-positive rate

Critics have reasonably argued that current UNHS practices produce a high rate of false-positive tests. False-positives refer to screen failures that turn out to have normal hearing. The false-positive test may result in a number of negative effects including parental misunderstanding and anxiety, unfavorable labeling, risk of iatrogenesis from additional, unnecessary diagnostic testing, and increased expense in term of time and money (Clemens & Davis, 2001). The presence of cerumen or vernix in the ear canal, middle ear effusion, and other causes of transient conduction hearing loss have been shown to interfere with OAE and ABR procedures and incur false-positive results (Sininger & Abdala, 1998).

Effect of external and middle ear conditions

Studies have been investigated the relationship between external and middle ear factors and hearing test results by DPOAE and ABR tests (Doyle, Burggraaff, Fujikawa, Kim, & Macarthur, 1997; Doyle, Rodgers, Fujikawa, & Newman, 2000). Ear canal debris and middle ear effusion are commonly found on newborns, which may produce mild, temporary conductive hearing loss and result in a “fail” result in the screening programme. Ear canal debris in newborns consists of vernix caseosa, a waxy substance that covers the skin of the newborn. In a study, a 13% prevalence of occluding vernix was found in infants 0 to 48 hours after birth (Doyle et al., 1997). External canal obstruction was significantly related to increased failure rate for OAE screening. Reported by Doyle et al. (1997), the OAE pass rate significantly increased from 76% to 90% after vernix was cleaned. The results were less dramatic for ABR assessment, where the pass rate improved from 88.5% to 91.5%, indicating the ABR was less sensitive to external canal obstruction. Spontaneous vernix clearance usually takes place during the first 24 to 48 hours after birth, but vernix may persist for over
Middle ear effusion, termed otitis media with effusion (OME) causes mild-to-moderate conductive hearing loss. Studies have estimated the incidence of mild ear effusion to be from 0% to 50% in newborn infants and it may persist even several weeks after initial detection (Doyle et al., 2000). Amniotic fluid is present in middle ear cavity during pregnancy, and may remain in the middle ear for several weeks after delivery (Bluestone & Klein, 1995). Fluid in the neonatal middle ear along with a negative pressure in the middle ear resulting from fluid absorption can induce a conductive hearing loss by reducing the mobility of the tympanic membrane and the ossicles, thus producing a decrease in the energy reaching the inner ear. Some studies have found that decreased tympanic membrane mobility due to the presence of the effusion accounts for a high percentage of screening failures; 50% of ears with decreased tympanic membrane mobility failed ABR and 62.5% failed OAE in one study (Doyle et al., 2000). Rosenfeld (1999) reported a 50% spontaneous resolution rate within one month, 60% by three months and 75% by six months in untreated OME. Therefore, false-positive rates can be minimized if assessment is performed after the clearance of the debris in the ear canal and the resolution of middle ear effusion. In the case of the MCHCs situation, this suggests that infants failing the second DPOAE screening because of conductive hearing loss resulting from OME are more likely to pass the ABR assessment if they undergo the assessment after resolution of OME. A longer time lag between the ABR assessment and the OAE screening, enabling spontaneous resolution of any otitis media, should contribute to a higher ABR assessment pass rate, and hence a lower false-positive rate.

**Solutions to minimize false-positive rate**

A number of studies had worked on the solutions to minimize false-positive rate of the screening programme. It is reported by many authors that approximately 60-90% of
initially referred ears following DPOAE screening passed the second screening. A two-stage process is therefore often suggested as retest after failure in first DPOAE screening is effective in reducing the false-positives rate (Mehl & Thomson, 1998; Wada et al., 2004; Watkin, 2001). Apart from that, reducing the false-positive rate by amending the screening criteria of the OAE screening has been discussed in various studies (Kennedy, Kimm, Thornton, & Davis, 2000; Wong, Chung, & Yu, 2004). According to Salata, Jacobson, & Strasnick (1998), a pass criterion of a 10-dB signal-to-noise ratio (SNR) produced the most reliable results compared with the ABR, with a resulting sensitivity and specificity of 67% and 68%, respectively. Regarding the effect of timeline on the screening outcomes, scheduling DPOAE screening after day 20 would minimize the false positive rate due to the clearance of the vernix in the ear canal (Ng, Hui, Lam, Goh, & Yeung, 2004).

A study that investigates at what age the effect of vernix and middle ear problems on DPOAE screening results occurs, as well as the effect of time lag between the second DPOAE screening and the ABR assessment on UNHS results would help those designing such programmes to determine the optimal timing of screening. To this author’s knowledge, no such study has been performed by any other researchers before. The goals of this study are therefore as follows: (1) to determine whether the age of infants at the second DPOAE screening and at the ABR assessment has an effect on the ABR passing rate; (2) to determine whether the duration of time lag between the second DPOAE screening and the ABR assessment has an effect on the ABR passing rate.

Method

Subjects in this study were 317 infants registered in the Yau Ma Tei Specialist Clinic Extension ENT/Audiology Center for diagnostic ABR assessment from 23 January 2001 through 28 December 2004. In order to be referred to this Center, the infants failed in the two
DPOAE screening tests administrated as part of the UNHS programme by the MCHCs in the Kowloon Cluster. There were 167 male infants and 150 female infants in the study group.

A two-stage hearing screening protocol was adopted by the MCHCs (see Figure 1). All infants registered in the MCHCs were screened using DPOAE. Infants who failed the initial DPOAE screening were rescheduled for the second DPOAE screening in MCHCs. In this study, infants who failed both DPOAE screenings were referred to the Yau Ma Tei Specialist Clinic Extension ENT/Audiology Center for diagnostic ABR assessment. Subsequent audiological monitoring was provided by qualified audiologists in the Yau Ma Tei Center to the infants who failed the diagnostic ABR assessment. Infants who passed either the first or the second DPOAE screening (who had failed the first DPOAE) were discharged from the program. However, routine hearing screening test was arranged between six and nine months of age for all MCHCs infants.

Figure 1. Universal Infant Hearing Screening Protocol in MCHCs.
DPOAE Procedure

The screening was performed in a quiet room adjacent to the main patient care area of the MCHCs without special acoustic treatment. The ambient noise levels in the testing rooms in different MCHCs in Hong Kong varied from 30 dBA to 54 dBA (MCHC, 1999). Screening was performed by a trained nurse. DPOAE were measured with a commercially available system (GSI 70 Automated OAE Screener), calibrated annually to manufacturer specifications. An acoustic probe enclosed with a soft rubber tip, and containing a miniature microphone and speaker, was used. This probe was placed but not hermetically sealed in the distal portion of the external auditory canal. The two pure tone stimuli (f₁ and f₂) were presented at 65 and 55 dB SPL, respectively. The cubic distortion product (2f₁-f₂) following simultaneous stimulation of two primary tonal stimuli (f₁ and f₂) was analyzed. The DPOAE amplitude and the noise floor in the adjacent frequency region of the distortion product (2f₁-f₂) were recorded. The screening pass criteria were defined as a gap of 10 dB or more between the mean noise floor and the DPOAEs amplitude at all three of the following three frequencies: 2000 Hz, 3000 Hz, and 4000 Hz (Salata et al., 1998).

ABR Procedure

Auditory brainstem responses were recorded using the Nicolet Viking Ile system. The procedure was conducted in an acoustically treated room by a qualified audiologist. The ABR assessment was performed on infants in a sleep state. An active electrode was placed on the vertex, a reference electrode was placed on the ear to be tested and the corresponding ground electrode was placed on the contralateral earlobe. The examination was conducted using click stimuli at a stimulation rate of 21 clicks/ms in an attempt to determine the auditory threshold (in dB SPL) for each ear, which was then transformed into dBHL equivalents. A classification system for evaluating ABR results was derived from data available in the literature. The following criteria were adopted: Normal hearing as thresholds
below/equal to 25 dB hearing loss in both ears; mild hearing loss as thresholds between 26 and 40 dB hearing loss; moderate hearing loss as thresholds between 41 and 55 dB HL; moderate-to-severe hearing loss as thresholds between 56 and 70 dB HL; severe hearing loss as threshold between 71 and 90 dB HL; and profound hearing loss as the absence of a response at 90 dB HL (Chan, Lee, Chow, Shek, & Mak, 1998). Infants who failed the ABR assessment would receive follow-up monitoring in the Yau Ma Tei clinic; behavioral audiometry was administrated to complete the pediatric evaluation of hearing sensitivity.

Data Analysis

ABR pass rates for groups of infants who (a) underwent the second DPOAE screening and ABR assessment at different ages, and (b) with different time lags between the second DPOAE screening and the ABR assessment would be compared to determine if a significant difference could be identified among the groups. A significant increase in ABR pass rate was expected for infants who underwent the DPOAE screening and the ABR assessment at older ages, as well as having a longer time lag between the second DPOAE screening and the ABR assessment.

Subsequent audiological findings, including whether the infants were found to have permanent hearing loss, and the type and severity of such hearing loss, were examined to verify the hypothesis that the low ABR pass rate could be attributed to transient mild to moderate conductive hearing loss caused by the presence of ear debris and/or middle ear effusion. It is expected that among the groups of infants who underwent the ABR assessment at a younger age, or having a shorter time lag between the second DPOAE screening and the ABR assessment, there should be (a) higher prevalence of normal hearing than prevalence of permanent hearing loss; (b) higher prevalence of conductive hearing loss than prevalence of sensorineural/mixed hearing loss; (c) higher prevalence of mild to moderate hearing than moderate to profound hearing loss.
Statistical Analysis

Effect of infant’s age and time lag between the second DPOAE screening and the ABR assessment on ABR pass rates was analyzed with a Pearson chi-square test. Pearson chi-square tests were also used for analyzing the prevalence of (a) normal hearing and permanent hearing loss, (b) conductive, and mixed and sensorineural hearing loss (SNHL) and (c) mild to moderate and moderate to profound hearing loss, in infants who failed the diagnostic ABR assessment. The significance level was taken as .05.

Results

Of the 317 subjects, 58% (184) of the infants passed and 42% (133) of the infants failed the ABR assessment. Of the 133 infants who failed, 52.6% (70) of the infants received subsequent monitoring by qualified audiologists in the clinic, the remaining 47.4% (63) infants failed to attend follow up in the clinic as scheduled and were thus unavailable for our review. In the current study, 62.2% (197) of attending infants underwent the ABR assessment before day 91, i.e., the three month period for identification of hearing loss in infants recommended by the JCIH (1995). The remaining 37.8% (120) infants underwent the ABR assessment between day 92 to day 403.

Effect of infant’s age at the tests on ABR pass rate

All infants underwent the second DPOAE screening between days 25 to 144 (mean = 46.1; S.D. = 15.9). The ABR assessment results are given in Table 1. The infants’ age at the second DPOAE screening did not significantly affect the ABR pass rate ($X^2=0.01, p>.05$) The same analysis was done for infants’ age at the time of ABR assessment; all infants underwent the ABR assessment between days 30 to 403 (mean = 86.8; S.D. = 40.2). The ABR assessment results are shown in Table 2. ABR pass rate increased significantly from 24% to
60.1% ($X^2=5.27, p<.05$) if the ABR assessment was performed after day 50.

Table 1

ABR pass rate for infants who underwent the second DPOAE screen before and after day 30

<table>
<thead>
<tr>
<th>Age at second DPOAE</th>
<th>Pass ABR</th>
<th>Fail ABR</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤30</td>
<td>12 (57.1%)</td>
<td>9 (42.9%)</td>
<td>21</td>
</tr>
<tr>
<td>&gt;31</td>
<td>172 (58.1%)</td>
<td>124 (41.9%)</td>
<td>296</td>
</tr>
<tr>
<td>Total</td>
<td>184 (58%)</td>
<td>133 (42%)</td>
<td>317</td>
</tr>
</tbody>
</table>

$X^2=0.01, p>.05$ (no significant difference; Chi-square with Yates’ Correction)

Table 2

ABR pass rate for infants who underwent the ABR assessment before and after day 50

<table>
<thead>
<tr>
<th>Age at ABR</th>
<th>Pass ABR</th>
<th>Fail ABR</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤50</td>
<td>12 (24%)</td>
<td>19 (76%)</td>
<td>31</td>
</tr>
<tr>
<td>&gt;51</td>
<td>172 (60.1%)</td>
<td>114 (39.9%)</td>
<td>286</td>
</tr>
<tr>
<td>Total</td>
<td>184 (58%)</td>
<td>133 (42%)</td>
<td>317</td>
</tr>
</tbody>
</table>

$X^2=5.27, p<.05$ (significant difference; Chi-square without Yates’ Correction)

Effect of time lag between the second DPOAE screening and the ABR assessment on ABR pass rate

Time lag between the second DPOAE screening and the ABR assessment range from one to 356 days (mean = 40.8; S.D. = 38.9). The ABR assessment results are given in Table 3. The ABR pass rate increased significantly from 41.8% to 64.6% ($X^2=13.90, p<.05$)
for the group with a time lag between the second DPOAE screening and the ABR assessment over 20 days.

Table 3

*ABR pass rate for infants having time lag between the second DPOAE and the ABR assessment under and over 20 days*

<table>
<thead>
<tr>
<th>Time lag (day)</th>
<th>Pass ABR</th>
<th>Fail ABR</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤20</td>
<td>38 (41.8%)</td>
<td>53 (58.2%)</td>
<td>91</td>
</tr>
<tr>
<td>&gt;21</td>
<td>146 (64.6%)</td>
<td>80 (35.4%)</td>
<td>226</td>
</tr>
<tr>
<td>Total</td>
<td>184 (58%)</td>
<td>133 (42%)</td>
<td>317</td>
</tr>
</tbody>
</table>

$X^2$=13.90, $p<.05$ (significant difference; Chi-square without Yates’ Correction)

*Subsequent audiological findings after behavioral audiology*

Subsequent audiological findings of the infants who failed the ABR assessment were investigated. Prevalence of normal hearing and permanent hearing loss is summarized in Tables 4 and 5. There was no significant difference for prevalence between the groups of infants who underwent the ABR assessment before and after day 50 ($X^2$=1.34, $p>.05$), as well as for groups of infants having a time lag between the second DPOAE screening and ABR assessment under and over 20 days ($X^2$=0.47, $p>.05$).
Table 4

Prevalence of normal hearing and permanent hearing loss (HL) on infants underwent the ABR assessment before and after day 50

<table>
<thead>
<tr>
<th>Age at ABR (day)</th>
<th>Normal Hearing</th>
<th>Permanent HL</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤50</td>
<td>3 (25%)</td>
<td>9 (75%)</td>
<td>12</td>
</tr>
<tr>
<td>&gt;51</td>
<td>28 (48.3%)</td>
<td>30 (51.7%)</td>
<td>58</td>
</tr>
<tr>
<td>Total</td>
<td>31 (44.3%)</td>
<td>39 (55.7%)</td>
<td>70</td>
</tr>
</tbody>
</table>

$X^2=1.34, p>.05$ (no significant difference; Chi-square with Yates’ Correction)

Table 5

Prevalence of normal hearing and permanent HL on infants having time lag between the second DPOAE and the ABR assessment under and over 20 days

<table>
<thead>
<tr>
<th>Time lag (day)</th>
<th>Normal Hearing</th>
<th>Permanent HL</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤20</td>
<td>11 (39.3%)</td>
<td>17 (60.7%)</td>
<td>28</td>
</tr>
<tr>
<td>&gt;21</td>
<td>20 (47.6%)</td>
<td>22 (52.4%)</td>
<td>42</td>
</tr>
<tr>
<td>Total</td>
<td>31 (44.3%)</td>
<td>39 (55.7%)</td>
<td>70</td>
</tr>
</tbody>
</table>

$X^2=0.47, p>.05$ (no significant difference; Chi-square without Yates’ Correction)

For infants diagnosed for permanent hearing loss, the type and severity of hearing loss was investigated, prevalence of conductive hearing loss and sensorineural hearing loss (SNHL) is given in Tables 6 and 7. There was no significant difference in prevalence between the groups of infants who underwent the ABR assessment before and after day 50 ($X^2=0.11, p>.05$), as well as for groups of infants having a time lag between the second
DPOAE screening and ABR assessment under and over 20 days ($\chi^2=0.84, p>.05$).

Table 6

**Prevalence of conductive HL, and mixed and SNHL on infants underwent the ABR assessment before and after day 50**

<table>
<thead>
<tr>
<th>Age at ABR (day)</th>
<th>Conductive HL</th>
<th>Mixed and SNHL</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤50</td>
<td>3 (33.3%)</td>
<td>6 (66.7%)</td>
<td>9</td>
</tr>
<tr>
<td>&gt;51</td>
<td>14 (46.7%)</td>
<td>16 (53.3%)</td>
<td>30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17(43.6%)</strong></td>
<td><strong>22 (56.4%)</strong></td>
<td><strong>39</strong></td>
</tr>
</tbody>
</table>

$\chi^2=0.11, p>.05$ (no significant difference; Chi-square with Yates’ Correction)

Table 7

**Prevalence of conductive HL, and mixed and SNHL on infants having time lag between the second DPOAE and the ABR assessment under and over 20 days**

<table>
<thead>
<tr>
<th>Time Lag (day)</th>
<th>Conductive HL</th>
<th>Mixed and SNHL</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤20</td>
<td>6 (35.3%)</td>
<td>11 (64.7%)</td>
<td>17</td>
</tr>
<tr>
<td>&gt;21</td>
<td>11 (50%)</td>
<td>11 (50%)</td>
<td>22</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17(43.6%)</strong></td>
<td><strong>22 (56.4%)</strong></td>
<td><strong>39</strong></td>
</tr>
</tbody>
</table>

$\chi^2=0.84, p>.05$ (no significant difference; Chi-square with Yates’ Correction)

Prevalence of mild to moderate, and moderate to profound hearing loss is shown in Tables 8 and 9. There was no significant difference of prevalence between the groups of infants who underwent the ABR assessment before and after day 50 ($\chi^2=0.16, p>.05$), as well as the groups of infants having a time lag between the second DPOAE screening and the
ABR assessment under and over 20 days ($X^2 = 0.63, p > 0.05$).

Table 8

*Prevalence of mild to moderate HL, and moderate to profound HL on infants underwent the ABR assessment before and after day 50*

<table>
<thead>
<tr>
<th>Age at ABR (day)</th>
<th>mild to moderate HL</th>
<th>moderate to profound HL</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤50</td>
<td>8 (88.9%)</td>
<td>1 (11.1%)</td>
<td>9</td>
</tr>
<tr>
<td>&gt;51</td>
<td>25 (83.3%)</td>
<td>5 (16.7%)</td>
<td>30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>33 (84.6%)</strong></td>
<td><strong>6 (15.4%)</strong></td>
<td><strong>39</strong></td>
</tr>
</tbody>
</table>

$X^2 = 0.16, p > 0.05$ (no significant difference; Chi-square with Yates’ Correction)

Table 9

*Prevalence of mild to moderate HL, and moderate to profound HL on infants with time lag between second DPOAE and the ABR assessment under and over 20 days*

<table>
<thead>
<tr>
<th>Time Lag (day)</th>
<th>mild to moderate HL</th>
<th>moderate to profound HL</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤20</td>
<td>13 (76.5%)</td>
<td>4 (23.5%)</td>
<td>17</td>
</tr>
<tr>
<td>&gt;21</td>
<td>20 (90.9%)</td>
<td>2 (9.1%)</td>
<td>22</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>33 (84.6%)</strong></td>
<td><strong>6 (15.4%)</strong></td>
<td><strong>39</strong></td>
</tr>
</tbody>
</table>

$X^2 = 0.63, p > 0.05$ (no significant difference; Chi-square with Yates’ Correction)
Discussion

Ear canal debris and middle ear effusion are two common causes for temporary conductive hearing loss in infants. Previous studies (Doyle et al., 1997; El-Refaie, Parker, & Bamford, 1996; Priner, Freeman, Perez, & Sohmer, 2003) addressed the significant increase in OAE and ABR referral rates resulting from the presence of the ear canal debris and middle ear effusion. It is therefore believed that the OAE and ABR pass rates would significantly increase if the infants undergo the tests after the clearance of the ear canal debris and resolution of middle ear fluid, which generally takes place in the first few weeks after birth (Doyle et al., 2000). OME most frequently occurs during the first two years of life, and may result in mild to moderate conductive hearing loss. Boone, Bower, & Martin (2005) reported that transient otitis media is a common cause of false positive failed newborn hearing screens (64%). Spontaneous resolution takes place within one month in 50% of infants, in 60% by three months, and in 75% by six months. An adequate time-lag between tests that enables resolution of possible otitis media, may contribute to a significant increase of the ABR pass rate. The objectives of this study were to evaluate the effect of the infant’s age at the time of testing, and the time lag between tests on the ABR pass rate and as a result, the likely false-positive rate of the screening programme. As expected, a significant effect of infant age at the time of ABR assessment, and the time lag between the second DPOAE screening and the ABR assessment, on the ABR assessment pass rate was obtained.

Effect of infant’s age at the tests

It was hypothesized that there should be a significant increase in the ABR pass rate if the tests were administrated after the clearance of the debris in the ear canal and the resolution of any potential middle ear effusion, which often takes place in the first few weeks after birth. The effect of the age at which the infants underwent the tests was therefore
investigated. In the present study, infant’s age at the second DPOAE screening does not significantly affect the ABR fail rate. It is reported in a previous study (Ng et al., 2004) that scheduling screening after day 20 would minimize false positive rate of the DPOAE screening. In this study, all infants involved underwent the second DPOAE screening at or after day 25. As expected, no significant effect of age difference beyond day 20 as proposed by Ng et al. (2004) can be found. For the age at the ABR assessment, the current study revealed a significant increase in ABR pass rate from 24% to 60.1% for the infants who underwent the ABR assessment after day 50. This may be partially attributed to the resolution of OME due to the clearance of the foetal middle ear fluid after birth (Doyle et al., 1997). In order to verify whether the test failure was due to the two conditions mentioned, infants should be evaluated using pneumatic otoscopy for the presence of vernix or debris, as well as the mobility of the tympanic membrane (Doyle et al., 2000). However, these procedures were not administered in the current UNHS programme.

Effect of time lag between the second DPOAE screening and the ABR assessment

OME is a common diagnosis among infants and is a significant cause of conductive hearing loss in this population (Boone et al., 2005), which may lead to failure in the screening tests. Infants who failed the second DPOAE screening because of transient conductive hearing loss resulting from OME are more likely to pass the ABR assessment if they undergo the assessment after resolution of OME. It is therefore believed that an adequate time lag between the ABR and the DPOAE tests that enables the spontaneous resolution of the otitis media could contribute to a higher ABR pass rate. Findings from the current study revealed a significant effect of time lag between the second DPOAE screening and the ABR assessment on the ABR assessment pass rate. ABR pass rate increased significantly from 41.8% to 64.6%, for a time lag of over 20 days between the second DPOAE screening and the ABR assessment. This can be partly attributed to the resolution of OME and restoration of normal
hearing during the interval between the second DPOAE screening and the ABR assessment. ABR pass rates can be affected by other factors including the persons who administrated the test, the equipment and location of testing. In the current studies, all ABR was recorded using the same Nicolet Viking IIe system, and the procedure was conducted in acoustically treated rooms by qualified audiologists.

Subsequent audiological findings after behavioral audiometry

In order to confirm that the high ABR fail rate was attributable to the transient conductive hearing loss caused by the presence of vernix and/or middle ear effusion, further research was undertaken. Subsequent audiological findings, including whether the infant was diagnosed with permanent hearing loss, as well as the type and severity of such hearing loss were noted. It was hypothesized that there should be more infants diagnosed to have normal hearing and a higher prevalence of mild to moderate conductive hearing loss than moderate to severe, sensorineural hearing loss for the groups of infants who underwent the ABR assessment before day 50, and having a time lag of over 20 days between the second DPOAE screening and the ABR assessment. However, a representative sample could not be obtained in the current study due to the high patient default rate (47.4%) for the follow-up audiological monitoring. Possibly due to the small sample size, a significant difference between the prevalence of normal hearing and permanent hearing loss, between the prevalence of conductive hearing loss and sensorineural hearing, and between mild to moderate and moderate to profound hearing loss among the groups could not be obtained in this study.

In this study, only 70 out of 133 (52.6%) infants who failed the ABR assessment received subsequent monitoring in the Yau Ma Tei clinic, the patient default rate (47.4%) was remarkably high, when compared with the default rates of 10% and 5.4% found in similar studies done in Hong Kong (Chan & Leung, 2004; Ng et al., 2004). A contributing factor for the high default rate was that many of mothers were from the mainland China. They often
returned to the mainland with their infants after the ABR assessment and failed to return for subsequent audiological monitoring. Furthermore, it maybe the case that some of the infants in the default group did not show any sign of hearing impairment due to the resolution of the otitis media and therefore their parents did not consider that subsequent audiological monitoring was necessary.

*Considerations for scheduling of the ABR assessment*

Scheduling of the ABR assessment after the age of day 50 and with a time lag between the second DPOAE screening and the ABR assessment of over 20 days could be a possible solution for minimizing the false-positive rate of the screening programme. However, in order to determine the optimal timing of screening to be performed, the following factors should be taken into account. Firstly, the primary purpose of the UNHS was to detect infants with hearing loss as soon as possible. It is recommended by the JCIH (1995) that all infants with hearing loss should be identified before three months of age, and receive intervention by six months of age because normal hearing is critical for speech and oral language development as early as the first six months of life (Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992). Delaying the timing of the screening may hinder the early detection of hearing loss before three months of age and as a result impede the speech and language outcomes for hearing impaired-children. From this study, 37.85% (120) of infants failed to complete the screening before day 91 and therefore did not meet the JCIH recommendations.

Secondly, positive (“refer”) screens engender substantial parental concern and anxiety and most parents can only feel relieved after diagnostic audiological assessment (Poulakis, Barker, & Wake, 2003). Lengthening the duration between the second OAE screening and the ABR may cause lasting negative emotions.

Thirdly, it is still unknown whether middle ear effusion present in the early neonatal period implies a greater risk for later otitis media (Doyle et al., 2000). Spontaneous resolution
of the temporary conductive hearing loss resulting from OME occurs in most infants (Rosenfeld, 1999). However, it has long been argued that otitis media, if persist enough in early life, may adversely after children’s language, speech, or cognitive development later in life, well after otitis media has resolved and hearing has returned to normal. Mixed and often contradictory results about the issue have been reported by previous studies of whether the association between persistent and/or recurrent early-life otitis media and later life impairment of language and/or speech and/or cognitive development exist (Gottlieb, Zinkus, & Thompson, 1979; Paradise et al., 2000; Shriberg et al., 2000). While criticized for the high false positive rates, the current hearing screening protocol does offer an opportunity for earlier diagnosis of otitis media (Boone et al., 2005). Administration of the ABR assessment after the resolution of the OME may increase the ABR pass rate but may result in omission of the diagnosis of the intermittent otitis media.

Limitations of the present study

The present study had a number of limitations. To begin with, the study is based on the hypothesis that the high test fails of the ABR assessment can be partly attributed to the administration of tests before the clearance of the debris in the ear canal and the resolution of middle ear effusion. The findings from this study match with the hypothesis. However, the hypothesis can only be confirmed after examination of the external and middle ear conditions of the infants who failed the tests while in this study, an expert external and middle ear assessment was not administrated. In addition, based on the above hypothesis, the effect of the presence of the debris in the ear canal and middle ear effusion should affect not only the ABR assessment results but also the DPOAE screening results. Accordingly, it is worth examining the DPOAE passing rate with the variation of the infant’s age at the time of the DPOAE screening, as well as the duration of the time lag between the two DPOAE screening tests. However, the data were not available in the current study. Furthermore, this study used
“infant” as the unit for statistical analysis. However, in a few cases, one of the ears of the infants failed the DPOAE screening but hearing loss was identified in another ear or both ears. It is therefore believed that somewhat more representative results could have been obtained if “ear” was used as the unit for analysis.

Further studies

Further research should continue studying the effects of screening and diagnostic assessment timing changes and the absolute duration of the time lag, as well as examination of the subsequent audiological findings of both infants who fail and pass the screening. Furthermore, studies should focus on the investigation of the prevalence of later otitis media on infants with otitis media in the early neonatal period, and the associations between persistent and/or recurrent early-life otitis media and later life impairment of language and/or speech and/or cognitive development.

Conclusion

In summary, an age of over 50 days at the time of ABR assessment and a time lag between the second DPOAE screening and the ABR assessment of over 20 days contributes to a significant decrease in the ABR fail rate. Further studies should provide detailed follow-up audiological examination on a representative sample of failed hearing screen cases to investigate whether the high early ABR fail rate is attributable to transient conductive hearing loss resulting from external canal obstruction and/or middle ear effusion. This would serve to confirm the association between the high ABR false-positive rate and external/middle ear factors, so as to help the screening programme planner to design the optimal timeline for the administration of the screening and diagnostic tests. If the hypothesis is verified, scheduling of the ABR assessment after the age of day 50 and with a time lag between the second DPOAE screening and the ABR assessment of over 20 days would help to minimize the false positive rate often associated with UNHS. However, this needs to be
balanced with consideration of the need to commence intervention for infants with hearing loss as early as possible (JCIH, 1995), as well as associated parental anxiety (Spivak, & Sokol, 2005). Furthermore, the association between the persistent and/or recurrent early-life otitis media and the speech and language, and cognition outcomes in later life should also be considered before scheduling of the tests.

Acknowledgments

The author would like to take this opportunity to thank Dr. McPherson, Bradley for his kind supervision, valuable comments and assistance throughout the study. Special thanks are dedicated to Mr Eddy C.M. Wong, Audiologist-in-Charge, and other staff from the Yau Ma Tei Specialist Clinic Extension ENT/Audiology Center for their full support in the study.
References


