Universal Newborn Hearing Screenings: A Three-Year Experience

Lisa Barsky-Firkser, PhD* and Shyan Sun, MD‡

ABSTRACT. **Objective.** To perform hearing screen- ings on all newborns before hospital discharge, using auditory brainstem evoked responses with analysis of time, cost, and failure rates to evaluate and determine the screening practicality.

**Method.** Over a 3-year period from January 1, 1993 to December 31, 1995, auditory brainstem evoked response screenings were performed on 15 749 infants born at Saint Barnabas Medical Center, Livingston, New Jersey, before their hospital discharge by certified/licensed audiologists. The auditory brainstem evoked response screenings were conducted using the Nicolet Compass Evoked Potential System.

**Results.** A 3-year experience of testing 15 749 infants proved to be a cost-effective program with costs less than $30.00/baby. To date, 46 babies have been identified with bilateral sensorineural hearing loss and 6 babies with unilateral sensorineural hearing loss.

**Conclusions.** The universal newborn hearing screening program at Saint Barnabas Medical Center has proved to be effective, beneficial, and necessary for an institution with more than 5000 births, annually. Early identification of hearing loss has resulted in infants receiving early intervention, and the screening program has provided education and follow-up services to both parents and physicians. Pediatrics 1997;99(6). URL: http://www.pediatrics.org/cgi/content/full/99/6/e4; auditory brainstem evoked responses, early hospital discharge of newborns, early identification of hearing loss, screening auditory brainstem evoked responses, universal newborn hearing screening.

**ABBREVIATIONS.** NIH, National Institutes of Health; ABR, auditory brainstem responses; NICU, neonatal intensive care unit; OAE, otoacoustic emission.

The Joint Committee on Infant Hearing, the National Institutes of Health (NIH), and the Healthy People 2000 initiative have all recommended screening of all newborns for hearing loss within the first 3 months of life.1-3 The growing trend of hospitals across the country to establish Universal Newborn Hearing Programs has initiated debates among health care providers as to the benefits, risks, and costs of such screening programs. The NIH consensus statement developed by a 15-member independent panel representing audiology, epidemiology, otolaryngology, pediatrics, speech-language pathology, and health care administrators recommended “Universal [Hearing] Screening be implemented for all infants within the first three months of life . . . [This] is most sufficiently achieved by screening prior to discharge.”2 Although several states have established or are developing statewide newborn hearing programs, there are still those in the field who claim that the available techniques for universal screenings are too costly and result in too many false positives to be used universally.4

The prevalence of newborn hearing loss has been estimated between 1.5 and 6.0/1000 live births.5,7 The average age of identification of children continues to exceed 12 months,9 and most often is between 24 to 30 months.2,9,10 Children with moderate hearing losses frequently are not identified until they are 5 to 6 years old when they receive screenings in school. The Joint Committee on Infant Hearing 1994 position statement recognizes the need for early detection and states “Because normal hearing is critical for speech and oral language development as early as the first six months of life it is desirable to identify infants with hearing loss before three months of age.” Once an infant is discharged from the newborn nursery or neonatal intensive care unit, there is a strong likelihood that the infant will fail to meet outpatient appointments for follow-up care. Schimizu et al11 reported that more than one-third of college-educated mothers failed to return their children for scheduled appointments, and more than two-thirds of mothers with a ninth grade education failed to do so.11 This is the reason that screening before discharge is strongly recommended.

We report 3-year data from a Universal Newborn Hearing Screening Program in one acute care medical center with more than 5000 births per year. The purpose of our initiation of Universal Newborn Screenings was to provide early identification of hearing loss, early intervention for rehabilitation, and education to parents and health care providers. Our mission was to heighten the awareness of the importance of early detection of hearing loss and of the necessity to begin early intervention services.

**OBJECTIVES**

The first objective in beginning this program was to perform hearing screenings on all newborns before their hospital discharge utilizing auditory brainstem responses (ABR). Second, we wanted to assess the time required for an adequate screening test. In addition, in experiencing the practicality of universal
hearing screenings in a setting of early newborn discharge, it was important that we observed the screening rate and failure rate of our population. Finally, to determine the practicality of a universal newborn hearing screening program, we needed to estimate the cost per baby of this testing at our institution.

**METHOD**

Figure 1 outlines the protocol for screening infants from the regular newborn nursery. These newborns were tested at approximately 4 hours after birth, at the time that they were out of the warming isolettes and placed in open cribs. Screening was performed at 35 dB HL. All testing was performed by licensed/certified audiologists with the Nicolet Compass ABR System (Natus Medical, Inc, San Carlos, CA). Jelly button disposable electrodes and insert earphones were used. If the infant passed the screening in both ears, he/she was discharged with no further follow-up. If there was a failure in one ear, parents and pediatricians were advised that the infant should be reevaluated at 6 months of age. If there was a failure in both ears, retesting was recommended at 3 months of age. Figure 1 shows that the bilateral failures confirmed at reevaluation were referred for immediate intervention and the unilateral failures were continually monitored on an annual basis.

In Figure 2, the protocol for testing infants with a high risk factor and those in the neonatal intensive care unit (NICU) is outlined. These newborns were screened at both 40 dB HL and 70 dB HL when they were medically stable, just before hospital discharge. The underlying factor is a high-risk condition that may be significant for progressive hearing loss that might not have been identified at birth. Therefore, infants with a high-risk criteria were referred for recall even if they passed the initial screening. The high-risk criteria, as outlined in the Appendix, are those 10 indicators associated with sensorineural and/or conductive hearing loss as identified in the Joint Committee on Infant Hearing 1994 Position Statement.

The reevaluation protocol for infants referred for follow-up from the Universal Newborn Screening Program (Fig 3) involved several procedures. A comprehensive case history was taken by the audiologist from the primary care giver accompanying the infant to the appointment. An otoscopic examination was performed as well as impedance testing to determine the mobility of the tympanic membrane, the presence or absence of middle ear fluid and/or infection, and to identify any possible tympanic membrane perforation. If on the initial, otoscopic examination and impedance testing, middle ear pathology was found, the infant was referred to the primary care physician for medical intervention and the audiological testing was not completed until after the middle ear pathology has resolved. Normal otoscopy and impedance measurements were followed by evaluation in the sound proof booth using Visual Reinforced Audiometrics to behaviorally determine awareness and startles for sounds of varying loudness and pitch levels. A diagnostic ABR evaluation was then completed and the last part of the evaluation is otoacoustic emission (OAE) testing to measure outer hair cell activity.

The composite results of the testing determined whether the infant was discharged, received continued follow-up, or received immediate intervention. The results dictated the focus of the counseling and education provided to the care givers. This is an essential component in the early identification of hearing loss. Family support and information was provided regarding early intervention activities, ongoing monitoring of infant’s medical and educational needs, amplification requirements, development of speech and language skills, and resources for financial assistance. This part of the universal newborn hearing screening program was an ongoing process that did not end after evaluation.

Infants and children with unilateral hearing loss are followed on at least an annual basis to monitor their hearing status as well as determine the need for intervention, especially as they enter school. When a bilateral hearing loss is confirmed, the evaluation and intervention involve a multidisciplinary approach by a team of professionals working with the parents or care givers. The team provides information on a wide variety of communication and educational choices allowing parents to make an informed decision for their child.

**RESULTS AND DISCUSSION**

The data were obtained from a total sample of 15,749 infants (1735 from NICU and 14,014 from regular nursery) screened at Saint Barnabas Medical Center in New Jersey from January 1, 1993 through December 31, 1995. During this period, 97% of all live births received hearing screenings before their hospital discharge.

Table 1 displays the failure and identification rates of the infants tested. The prevalence of sensorineural hearing loss in this institution during the 3-year period studied was established at 3.3/1000 live births. This prevalence rate is in agreement with current research. Northern and Downs originally reported that 1 in 1000 infants demonstrate significant hearing loss at birth. Including moderate sensorineural hearing losses the prevalence rate has been reported as high as 6/1000 live births. The high prevalence rate of 13/1000 in this institution’s NICU can be attributed to the severity of diseases and high risk factors characteristic of this NICU population. Saint Barnabas Medical Center is a level III Regional Perinatal Center accepting transports of high-risk obstetric as...
well as neonatal patients from surrounding hospitals. The medical center also has a large regional craniofacial center. Therefore, the degree of disability, including hearing loss, found in these infants may be significantly higher than in other institutions.

The 3% of infants not tested in each nursery represents early discharge, parental refusal, poor prognosis, and infants who were transferred to other institutions for continued medical care. Staffing the hearing screening program 365 days a year is necessary to be a truly universal program and attempt to screen all infants. Despite a 32% early discharge rate (≤ 24 hours) testing of 97% of infants before discharge was a major accomplishment.

ABR, as our chosen screening mode, does not require a voluntary response and was performed without sedation. This testing has been proven with a sensitivity rate for sensorineural hearing loss of 0.98 and a specificity of 0.95. The high pass rate (97%) is a significant improvement from earlier years of ABR screening due to the equipment sophistication and comprehensive hands-on training for audiologists performing these tests.

The screening time per infant was an issue to be addressed to minimize interference in the nurseries and to make efficient use of our audiologists’ time. In the first 3 years of our program, we closely studied the screening time per infant. As outlined in Table 2, in 1993 the original mean time per infant was 15 minutes, 20 seconds and by 1995 this time had been significantly reduced to 9 minutes, 1 second with the shortest test completing at 4 minutes, 20 seconds and the longest at 25 minutes, 20 seconds. This wide range of testing time reflects of the infant’s activity and comfort. Optimal testing is performed when the infant is in a sleeping state after feeding. There is also slight time variability among audiologists. Our present mean time of less than 10 minutes certainly makes our program very efficient with minimal disturbance for nursery staff and parents.

The results of our final objective to analyze the cost per infant is outlined in Table 3 based on 5000 infants. The cost per infant of just under $30.00 dem-

<table>
<thead>
<tr>
<th>TABLE 1. Screening, Failure, and Identification Rates*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Newborn nursery</strong></td>
</tr>
<tr>
<td>Total infants</td>
</tr>
<tr>
<td>Tested</td>
</tr>
<tr>
<td>Not tested</td>
</tr>
<tr>
<td>Passed/no referral</td>
</tr>
<tr>
<td>Passed/HR referral</td>
</tr>
<tr>
<td>Failed</td>
</tr>
<tr>
<td>Identified sensorineural hearing losses</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>NICU</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total infants</td>
</tr>
<tr>
<td>Tested</td>
</tr>
<tr>
<td>Not tested</td>
</tr>
<tr>
<td>Passed/no referral</td>
</tr>
<tr>
<td>Passed/HR referral</td>
</tr>
<tr>
<td>Failed</td>
</tr>
<tr>
<td>Identified sensorineural hearing losses</td>
</tr>
</tbody>
</table>

*Outline of the screening, failure, and identification rates for 3 years of data from the Universal Newborn Hearing Screening program at Saint Barnabas Medical Center. Identified sensorineural hearing losses were confirmed at 6-month and 1-year follow-up visits. Overall prevalence rate for this institution was established at 3.3:1000 live births.
TABLE 2. Testing Time*

<table>
<thead>
<tr>
<th></th>
<th>1993</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. infants tested</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>No. audiologists</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Shortest test time</td>
<td>8 min 10 sec</td>
<td>4 min 20 sec</td>
</tr>
<tr>
<td>Longest test time</td>
<td>29 min 5 sec</td>
<td>25 min 2 sec</td>
</tr>
<tr>
<td>Mean test time</td>
<td>15 min 20 sec</td>
<td>9 min 1 sec</td>
</tr>
<tr>
<td>SD</td>
<td>6 min 20 sec</td>
<td>2 min 55 sec</td>
</tr>
</tbody>
</table>

* Testing time was calculated from start of preparation of infant’s skin for electrode placement to end of test, after the electrodes were removed.

TABLE 3. Cost Analysis (5000 Infants)

<table>
<thead>
<tr>
<th>Category</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manpower (salary and benefits)</td>
<td>$100,000</td>
</tr>
<tr>
<td>2 Full time audiologists</td>
<td>$25,000</td>
</tr>
<tr>
<td>1 Per diem audiologist</td>
<td>$6,500</td>
</tr>
<tr>
<td>1 Secretary (15 h/wk)</td>
<td>$9,360</td>
</tr>
<tr>
<td>Equipment</td>
<td></td>
</tr>
<tr>
<td>2 Nicolet compass (amortized 5 y)</td>
<td>$6,400</td>
</tr>
<tr>
<td>Disposables</td>
<td>$25,000</td>
</tr>
<tr>
<td>Other supplies</td>
<td>$2,500</td>
</tr>
<tr>
<td>Total cost</td>
<td>$149,760</td>
</tr>
<tr>
<td>Cost per infant</td>
<td>$29.95</td>
</tr>
</tbody>
</table>

Indicates that universal newborn hearing screening is not only feasible, but also very cost efficient.

The National Consortium on Universal Newborn Hearing Screening conducted a survey in August 1995 of screening programs across the country (White KR. National Consortium for Universal Newborn Hearing Screening: survey of universal newborn hearing screening programs, unpublished data, 1995). The results of this survey indicated that Saint Barnabas Medical Center is only one of two hospitals in the country performing conventional ABR as a 1-step screening mode for the newborn program. There were 79 other hospitals in the United States with reported universal screening programs, however, all of these institutions use a 2-step screening technique with OAE or automated ABR as the first stage and conventional ABR as the second stage.

The NIH consensus statement recommended a 2-stage screening procedure using OAE as a cost effective means of eliminating all infants with normal hearing sensitivity and ABR for the second stage to confirm the accuracy of the OAE result and determine the need for diagnostic evaluation. The cost of OAE screening has been documented at less than $25.00 per infant. Time required to complete OAE is reported with a range of 5 to 20 minutes. Additional time and cost is then accumulated for the second stage ABR procedure.

Conventional ABR has long been recognized as the most sensitive method of assessing the auditory acuity of newborns. However, it was thought to be too expensive and time-consuming a procedure for initial stage screening. Our data of a cost of less than $30.00 per baby and a mean testing time of 9 minutes, 1 second demonstrate the viability of using conventional ABR screening for a 1-stage procedure. We believe 1-stage ABR screening saves time and money.

The past 3 years’ experience involved screening of 15,749 infants. To date, 52 infants have been identified and confirmed with sensorineural hearing loss. Intervention for amplification, speech and language development, and family education has begun for all these infants.

CONCLUSIONS

Universal newborn hearing screenings are becoming a national practice and in several states a standard of care. The failure to identify hearing loss within the first few months of age may result in spirited legal actions. Hospitals and physicians face the challenge of complying with the prevailing standard of care to minimize risk of liability and maximize childhood potential.

Saint Barnabas Medical Center’s universal newborn hearing screening program is now completing its fourth year. The reported 3-year experience provided the foundation for a program that continues to grow and change. Presently, all infants who fail the initial screening are referred for re-evaluation within 1 month, rather than using a 3-month recall as we reported. We are presently collecting data to determine if there is a significant difference in the return rate for reevaluation. Our goal in shortening the time lapse between first screening and recall is to identify hearing impairment and begin early intervention as early as possible.

Infants who pass the initial screening and are recalled for future testing due to a high-risk indicator identified by the Joint Committee on Infant Hearing, are being followed to determine if all 10 of these risk factors are related to progressive hearing loss as opposed to congenital hearing loss. Our present objective is to identify the number of these children with progressive hearing impairments to determine the validity of following these infants.

Pediatricians and audiologists must work as a team for early identification and treatment. Pediatricians should take a proactive role in developing newborn hearing screening programs and in the initiation of follow-up programs to provide a continuity of care for these infants. Pediatricians should be the team leaders in the multidisciplinary approach to management of hearing impairment. Existing programs will be the foundation for effectuating the standard of care into the 21st century.

APPENDIX: JOINT COMMITTEE ON INFANT HEARING—1994 POSITION STATEMENT

Indicators Associated with Sensorineural and/or Conductive Hearing Loss

1. Family history of hereditary childhood sensorineural hearing loss.
2. In utero infection such as cytomegalovirus, rubella, syphilis, herpes, and toxoplasmosis.
3. Craniofacial anomalies, including those with morphological abnormalities of the pinna and ear canal.
4. Birth weight less than 1500 g (3.3 pounds).
5. Hyperbilirubinemia at a serum level requiring exchange transfusion.
6. Ototoxic medications, including but not limited to the aminoglycosides, used in multiple courses or in combination with loop diuretics.
7. Bacterial meningitis.
8. Apgar scores of 0 to 4 at 1 minute or 0 to 6 at 5 minutes.
9. Mechanical ventilation lasting 5 days or more.
10. Stigmata or other findings associated with a syndrome known to include a sensorineural and/or conductive hearing loss.

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