Universal Infant Hearing Screening: Successes and Continuing Challenges

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The value of identifying permanent hearing loss during the first few months of life and providing effective treatment to ameliorate or even eliminate the negative consequences associated with hearing loss has been recognized for many decades. More than 70 years ago, Ewing and Ewing (1944) called for

"… an urgent need to study further and more critically methods of testing hearing in young children … during this first year the existence of deafness needs to be ascertained ... training needs to be begun at the earliest age that the diagnosis of deafness can be established."

Unfortunately, improvements in achieving this goal were discouragingly gradual or non-existent until the early 1990s. At that time, technological advances in screening and diagnostic equipment, improved hearing technology, government-funded demonstration programs in a few countries, and recommendations by various professional societies and organizations created a revolution in our ability to identify and provide services to infants and young children with hearing loss and their families.

Even though the benefits of identifying congenital hearing loss during the first few months of life had been recognized for decades (Ewing and Ewing 1944; Downs and Sterritt 1964; Babbidge 1965), the belief that it could actually be achieved is relatively new. For example, as recently as 1996, the United States Preventive Services Task Force (USPSTF 1996) noted that "congenital hearing loss is a serious health problem associated with developmental delay and speech and language function" but concluded that "there is little evidence to support the use of routine universal screening for all neonates." A short time later, a widely cited article in *Pediatrics* (Paradise 1999) noted that

"… universal newborn hearing screening in our present state of knowledge is not necessarily the only, or the best, or the most cost-effective way to achieve [early identification of hearing loss] and more importantly … the benefits of universal newborn hearing screening may be outweighed by its risks."

Current Status of Early Hearing Detection and Intervention Programs in the United States

Despite the widely-held belief during the 1980s that universal newborn hearing screening was impractical, Dr. C. Everett Koop, when he was serving as the Surgeon General of the United States in 1989, issued a challenge that led to dramatic improvements in how newborn hearing screening is done.

"The harmful effects of childhood hearing impairment are given little thought by many people because hearing loss is largely an invisible handicap. An infant with a hearing impairment is generally healthy-looking and develops relatively normally during the first year of life. But if a hearing loss goes undetected in that first year, it will interfere tragically with the child's ability to learn to speak, to do well in school, and to contribute productively to society. … In 1989, when I was Surgeon General of the United States, I challenged parents, physicians, state agency staff, and researchers to work together to find better ways to identify very young children with hearing impairments. I set a goal that by the

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year 2000 all children with significant hearing impairments would be identified before 12 months of age. Although it was an ambitious goal, I was optimistic that it would be accomplished" (Koop 1993).

Dr. Koop's enthusiasm for newborn hearing screening and his optimism that it could be successful was somewhat surprising given that fewer than 3% of all newborns in the United States were being screened for hearing loss at that time, and even less newborn hearing screening was occurring in other parts of the world (White 2003).

In response to Koop's challenge, a number of successful research and demonstration projects established the feasibility and accuracy of universal newborn hearing screening in the early 1990s (White and Behrens 1993; Mehl and Thomson 1998; Wessex 1998). As shown in Figure 1, the number of newborns being screened for hearing loss has grown steadily, and 98% of newborns in the United States are now being screened for hearing loss (CDC 2010a).

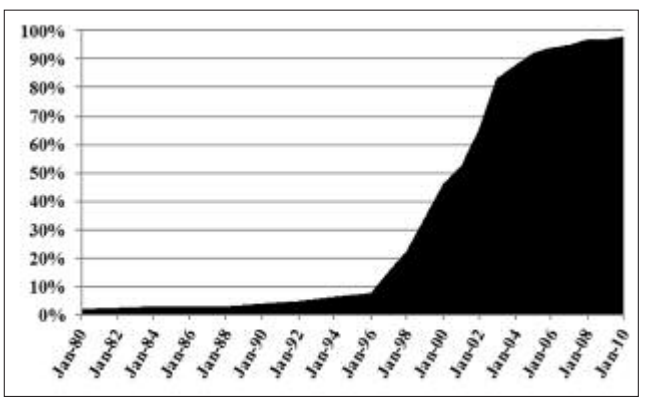

Figure 1. Percentage of newborns screened for hearing in the United States.

In 1993 the United States National Institutes of Health convened a Consensus Development Panel to review the evidence about how early identification of hearing loss could be done most efficiently and make recommendations to improve practice. The Panel concluded that: "All hearing impaired infants should be identified and treatment initiated by six months of age … [T]he Consensus Panel recommends screening of all newborns for hearing impairment prior to discharge" (NIH 1993). A few years later, the European Consensus Development Conference on Neonatal Hearing Screening concluded that "… identification by screening at or shortly after birth has the potential to improve quality of life and opportunities for those affected … implementation of neonatal screening programs should not be delayed" (Grandori 1999). In 1999, the American Academy of Pediatrics endorsed "universal [hearing] screening of all infants" (AAP 1999). Other organizations, including the American Speech-Language Hearing Association, the American Academy of Audiology, the National Association of the Deaf, March of Dimes, and the American College of Medical Genetics soon followed suit (NCHAM 2010), and then in 2000, the Joint Committee on Infant Hearing issued what has come to be viewed as a definitive set of guidelines for how to implement universal newborn hearing screening programs and connect those programs to diagnostic, early intervention, health care, and family support activities (JCIH 2000).

The success of universal newborn hearing screening programs in the United States led to dramatically reducing the age at which children with permanent hearing loss were identified. As shown in Figure 2, the average age of identification dropped from 24–30 months of age to 2–4 months of age in those parts of the country where screening programs were well connected to diagnosis and early intervention activities.

The number of children identified in successful universal newborn hearing screening programs was also substantially higher than what most people had previously assumed to be the case (Northern and Downs 1974). As shown in Table 1, successful universal newborn hearing screening programs in the United States are routinely identifying 2-4 children per 1000 with confirmed permanent hearing loss.

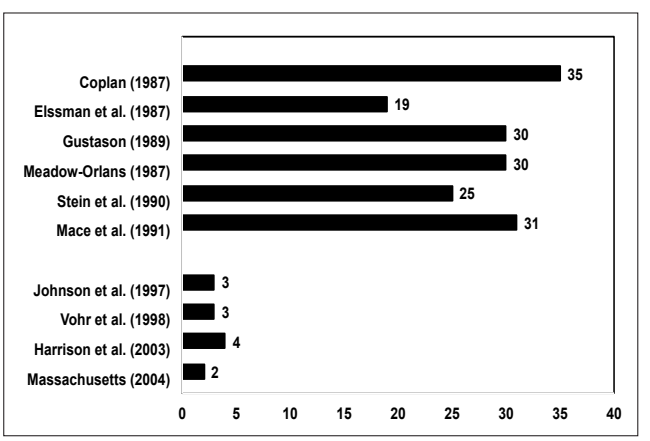

Figure 2. Age in months at which permanent hearing loss was diagnosed.

Site	Sample Size	Prevalence Per 1000	% of Refers with Diagnosis
Texas (Finitzo et al 1988) (1/94 to 6/97)	54,228	2.15	31%
Colorado (Mehl & Thomson, 1998) (1/92 to 12/96)	41,976	2.56	48%
New Jersey (Barsky-Firkser Sun, 1997) (1/94 to 6/97)	15,749	3.30	41%
Hawaii (Johnson et al 1997) (1/96 to 12/96)	9,605	4.15	98%
Massachussets (2004) (1/04 to 12/04)	78,515	2.87	89%

Table 1: Rate per 1000 of permanent childhood hearing loss in EHDI programs.

Even though the numbers of children with hearing loss identified by the screening programs shown in Table 1 is higher than many people expected, this prevalence level is consistent with the results of the National Health and Nutrition Examination Surveys (NHANES 2011) for 6 through 18 year-old children in the United States. The NHANES surveys are broad, multi-purpose surveys conducted periodically for a nationally-representative sample of civilian non-institutionalized people in the United States within selected age ranges. The NHANES data are arguably the best and most reliable data available about the prevalence of hearing loss because they are based on actual examinations instead of results of questionnaires. Prevalence rates were quite similar in these two nationally-representative samples as shown in Table 2.

Unfortunately, the NHANES data do not report hearing losses due to temporary ear infections separately from those with permanent hearing losses. Thus, some of the hearing losses in the "mild bilateral" and the "unilateral" categories of the NHANES data were likely temporary hearing losses. However, all of the moderate, severe, and profound bilateral losses are likely permanent. Although it is impossible to be sure, if we conservatively estimate that 25% of the losses in the mild bilateral and unilateral categories are permanent, about 2% of 6-18 year-old children have permanent hearing loss. These estimates are consistent with

	NHANES II (1976-80) (n=7,119)		NHANES III (1988-94) (n=6,166)	
	Sub-category	cumulative	Sub-category	cumulative
Profound Bilateral	0.75	**0.75**	0.57	**0.57**
Severe Bilateral	0.51	**1.26**	0.28	**0.85**
Moderate Bilateral	2.37	**3.63**	1.66	**2.51**
Mild Bilateral	13.70	**17.33**	13.80	**16.31**
Unilateral (mild, moderate, severe)	49.00	**66.33**	57.00	**73.31**

Table 2: Summary of data from NHANES on prevalence per 1000 of hearing loss for 6–19 year old children in the United States.

Goal 1. ***All newborns will be screened for hearing loss before 1 month of age, preferably before hospital discharge.***	Hospitals will have a written protocol to ensure all births are screened, results are reported to the infant's parents and primary health care provider and referred infants (≤ 4%) are referred for diagnostic evaluation. Demographic data will be collected for each infant and appropriate educational material provided to parents. States will reduce/eliminate financial barriers to screening and ensure screening of out-of-hospital births.
Goal 2. ***All infants who screen positive will have a diagnostic audiologic evaluation before 3 months of age.***	States will develop audiologic diagnostic guidelines and maintain a list of qualified providers to ensure infants referred from screening receive a comprehensive audiologic evaluation before 3 months of age and are referred to appropriate services. States will provide appropriate education and/or training about diagnostic audiologic evaluation to parents, primary health care providers, and audiologists.
Goal 3. ***All infants identified with hearing loss will receive appropriate early intervention services before 6 months of age (medical, audiologic, and early intervention)***	States will develop policies and Resource Guides to ensure all parents of children with hearing loss receive appropriate medical (including vision screening and genetic services), audiologic, and early intervention services (based on the communication mode chosen by the family). States will ensure that early intervention service providers are educated about issues related to infants and young children with hearing loss
Goal 4. ***All infants and children with late onset or progressive hearing loss will be identified at the earliest possible time.***	Hospitals and others will report information about risk factors for hearing loss to the state, who will monitor the status of children with risk factors and provide appropriate follow-up services.
Goal 5. ***All infants with hearing loss will have a medical home as defined by the American Academy of Pediatrics.***	A primary care provider who assists the family in obtaining appropriate services will be identified for all infants with confirmed hearing loss before 3 months of age. The state will provide unbiased education about issues related to hearing loss for parents and medical home providers.
Goal 6. ***Every state will have an EHDI Tracking and Surveillance System that minimizes loss to follow-up.***	A computerized statewide tracking and reporting system will record information about screening results, risk-factors, and follow-up for all births. The system will have appropriate safeguards, be linked to other relevant state data systems, and be accessible to authorized health care providers.
Goal 7. ***Every state will have a system that monitors and evaluates the progress towards the EHDI Goals and Objectives.***	A systematic plan for monitoring and evaluation will be developed and implemented by an Advisory Committee to regularly collect data and provide feedback to families and ensure that infants and children with hearing loss receive appropriate services.

Table 3: National Goals for Early Hearing Detection and Intervention Programs

a report by the American Speech-Language Hearing Association (ASHA 1993) that by 6 years of age, the incidence of permanent hearing loss more than triples from three per 1000 to ten per 1000. Based on data from successful newborn hearing screening programs listed in Table 1, the NHANES survey results, and estimates from ASHA, we should expect effective newborn hearing screening programs in the United States to identify about three children per 1000 with permanent hearing loss.

The rapid development of universal newborn hearing screening programs in various States also led to the federal government becoming involved to provide support and assistance (White, Forsman, Eichwald and Munoz 2010). For example, in 1988, the Federal Maternal and Child Health Bureau began requiring States to report the percentage of newborns screened for hearing impairment before hospital discharge, and in 2000 federal funding became available to assist States in establishing a system for screening, diagnosing, and enrolling children with hearing loss in early intervention programs. As a part of this system, the Maternal and Child Health Bureau and the Centers for Disease Control and Prevention established national goals for all early hearing detection and intervention programs (CDC 2010b) as summarized in Table 3.

Global Expansion of Newborn Hearing Screening

The practicality and value of newborn hearing screening are also being recognized by many other countries. Based on published reports in the literature, at least six other countries are screening more than 90% of their births (Austria, Netherlands, Oman, Poland, Slovakia and the United Kingdom), and an additional nine countries are screening 30-89% of their births (Australia, Belgium, Canada, Germany, Ireland, Philippines, Russia, Singapore and Taiwan). Published reports of smaller scale newborn hearing screening programs in at least 46 other countries document the progress towards establishing national universal newborn hearing screening programs. Appendix A includes a listing of countries that are doing hearing screening in each of these groups and references to published articles about their newborn hearing screening systems.

In 2009 the World Health Organization (WHO) convened a group of experts from throughout the world to summarize current issues and guiding principles for action related to newborn and infant hearing screening (WHO 2010). This working group's report was in response to Resolution 48.9 by the 48th World Health Assembly that urged member states "to prepare national plans for early detection in babies, toddlers and children." A previous WHO expert working group had "recommended that a policy of universal neonatal screening be adopted in all countries and communities with available rehabilitation services and that the policy be extended to other countries and communities as rehabilitation services are established."

Even though many countries are working toward universal newborn hearing screening, the WHO expert working group recognized that there are still many countries where the implementation of a universal newborn hearing screening program is considered to be too costly and/or its value is questioned. Furthermore, in those countries where widespread newborn hearing screening programs exist, there is often no consistent approach, and issues such as quality control, screening methods, and follow-up are frequently not well understood. The reason for such variation is not always financial — some wealthy countries have fragmented and ineffective programs, while other less-wealthy countries have very successful early hearing detection and intervention programs. As noted in the report issued by this expert working group, "Quality assurance issues in particular are vital to successful newborn and infant hearing screening and related interventions — in some settings, it is estimated that the poor training and performance of screeners renders up to 80% of screening useless" (WHO 2010).

Even though there is widespread agreement that the best approach to early identification of hearing loss is universal newborn hearing screening using a physiological measure such as otoacoustic emissions or auditory brainstem response, some countries cannot implement such programs because of limited financial resources or because appropriate equipment and personnel are not available. Consequently, the WHO report recommended that family questionnaires or behavioral testing be considered in situations where physiological testing was not feasible.

Questionnaires can be used to ask parents or other caregivers about the response of their neonate or infant to sounds and their use of language, including early indicators of language such as babbling and other vocalizations. Babies who perform poorly on such measures can then be referred for more comprehensive audiological assessment. Even though parents' responses to such questionnaires are not as accurate as physiological

screening, there is evidence that a significant number of infants and young children with permanent hearing loss can be identified using such methods (Kiese-Himmel and Kruse 2005; Ozcebe, Sevinc and Belgin 2005; Gopal, Hugo and Louw 2001).

Behavioral measures, such as simple noisemakers or other more sophisticated audiological procedures and equipment, can also be used to identify hearing loss. However, such methods produce high levels of both false negatives and false positives with babies less than 12 months of age. For example, Watkin, Baldwin, and Laoide (1990) did a retrospective analysis in England of over 55,000 children 2–15 years of age who had completed a behavioral evaluation for hearing when they were 7–12 months of age. Of the 39 children later identified with severe to profound bilateral losses, only 44% were identified when they were 7–12 months old based on the behavioral evaluation. The remaining children were identified later based on a school-age screening program, a parent concern, or by a health care provider. For children with mild to moderate bilateral hearing losses and children with unilateral hearing losses, the behavioral evaluation at 7–12 months of age identified only 25% and less than 10%, respectively. Even when home visitors are specifically trained to do behavioral evaluations of hearing in a home setting, most young children with hearing loss will be missed by such procedures.

Thus, in situations where it is not possible to use physiological testing to do hearing screening of infants and young children, the use of family questionnaires or behavioral evaluations will identify some children with hearing loss. However, many children with hearing loss will also be missed. Therefore, family questionnaires and behavioral testing should be considered only as an interim step in working towards a program of universal newborn hearing screening based on physiological testing.

The WHO (2010) report also recommended that when it is not feasible to implement universal hearing screening programs for all newborns, it may be possible to begin a hearing screening program by focusing on a subset of infants and young children. For example, when newborn hearing screening programs are being established, it is not unusual to focus on babies in a particular geographical region because they are more accessible or because equipment and personnel are more available. Also, because the incidence of permanent hearing loss is much higher among neonates who require intensive medical care during the first few days of life, hearing screening programs that are unable to screen all babies can focus on those admitted to a neonatal intensive care unit. Many studies have shown that babies who exhibit risk factors associated with hearing loss have a much higher rate of hearing loss than those who do not (Pappas and Schaibly 1984; Feinmesser, Tell and Levi 1986; Elssman, Matkin and Sabo 1987; Mauk, White, Mortensen and Behrens 1991). It is important to recognize, however, that more than 95% of the babies who have one of the risk factors identified by the Joint Committee on Infant Hearing do not have hearing loss and that approximately half the babies who do have congenital hearing loss will not exhibit any risk factors (Mauk et al. 1991). Thus, even the best risk-based newborn hearing screening program will only identify half of the babies with permanent hearing loss. Furthermore, the risk factors which are most predictive of hearing loss in babies will vary from country to country, so it is important to have local data about the sensitivity and specificity of risk factors before using this as a method of identifying children with hearing loss.

Regardless of the type of hearing screening program that is implemented, the WHO report (2010) emphasized that all newborn hearing screening programs need to have:

- Clearly stated goals with well-specified roles and responsibilities for those people who are involved.
- A clearly designated person who is responsible for the program.
- People doing the screening who have received hands-on training in what they are expected to do.
- Regular monitoring to ensure that the protocol is being correctly implemented.
- Specific procedures about how to inform parents of results.
- Recording and reporting of information about the screening for each child in a health record.
- A documented protocol based on local circumstances.

If these guidelines can be met, then the implementation of successful newborn hearing screening programs is achievable in many countries. Successful programs have already been implemented as shown in Appendix A using a variety of screening methods, protocols and linkages to existing healthcare social and educational systems. These programs have demonstrated the benefits of early hearing detection and intervention. The WHO report (2010) concluded by stating that:

"… the aims of [newborn hearing screening] programmes are widely accepted as both highly worthwhile and attainable and … should be expanded to

include all neonates and infants. Although universal newborn hearing screening using OAE or AABR should be the goal for all countries, interim approaches using targeted screening based on questionnaires, behavioural methods and/or physiological methods guided by evidence from well-conducted pilot studies will also be beneficial. Whatever approach is used, it is important that the EHDI programme is linked to existing health care, social and educational systems, and that the procedures and outcomes of the programme be documented so that ongoing quality assurance activities can be implemented and experiences shared."

Challenges to Successful Early Hearing Detection and Intervention Programs

In all parts of the world where newborn hearing screening and intervention programs have been implemented, there are still many challenges. Certainly, many infants and young children with hearing loss are being identified and provided with services that enable them to achieve far beyond what was considered possible 30 years ago. Nonetheless, even in places where universal newborn hearing screening is being done, many challenges remain. Examples of six frequently encountered challenges are summarized below.

Loss to Follow-Up/Documentation

There is widespread agreement that the most urgent area where more work is needed — and the one that gets the most attention — is making sure that infants and young children who fail their newborn hearing screening test receive timely and appropriate diagnostic evaluations to determine whether hearing loss is present. Unfortunately, analysis of recent data reported to the United States Centers for Disease Control and Prevention (CDC 2010a) for 2008 showed that of the 2.1% of infants referred for follow-up after newborn screening, only 68.1% were documented as having received a diagnostic evaluation. Such loss to follow-up occurs for a variety of reasons including the following.

1. Too many newborns are failing hospital-based hearing screening because of poorly trained screeners, poorly maintained equipment, and/or use of inefficient protocols.
2. Many parents are not given effective information about initial results, need for follow-up, what to do next, etc.
3. Accurate screening results are not shared quickly with the people who need to do follow-up, including hospitals, state EHDI programs, health care providers, audiologists, early interventionists, etc.
4. There is a shortage of pediatric audiologists, particularly in rural/remote areas because of not enough training programs and poor reimbursement rates for services to infants and young children.
5. Many program managers, health care providers, and early interventionists are not aware of what constitutes "best practices".
6. There is not enough public awareness about the importance of early identification of hearing loss among taxpayers, administrators, extended family, etc.
7. Insufficient resources are committed to EDHI programs for screening, follow-up diagnosis, early intervention, case management, etc.

Reducing loss to follow-up and loss to documentation will require sustained and coordinated efforts to address all of the factors listed above. The problem will not be solved with a better computer program for tracking and data management.

Identifying Hearing Loss in Young Children

In addition to making hospital-based screening programs as efficient as possible, public health officials should be aware of the need to continue doing hearing screening during the early childhood years. Regular hearing screening as a part of day-care and preschool programs, or during well-child visits to health care providers, can be a useful tool for detecting late-onset permanent hearing loss, as well as hearing loss that is missed during newborn hearing.

The American Speech-Language Hearing Association (ASHA 1993) estimates that the incidence of permanent hearing loss more than triples from three per 1,000 to three per 300 by the time children are 5 years of age. For these children to be identified in a timely manner, systematic hearing screening at periodic intervals will be necessary. Unfortunately, after the newborn period, very few 0-5 year-old children are regularly screened for hearing loss using objective screening tools. In a positive step towards the goal of systematic hearing screening during the early childhood years, the American Academy of Pediatrics recently recommended that all children receive:

"… an objective standardized screening of global development with a validated assessment tool at 9, 18, and

24 to 30 months of age or at any time if the health care professional or family has concern … Infants who do not pass the speech-language portion of a medical home global screening or for whom there is a concern regarding hearing or language should be referred for speech-language evaluation and audiology assessment" (JCIH 2007).

However, implementing hearing screening in physicians' offices will not be easy, as shown by how difficult it has been to get health care providers to do a quick, subjective hearing screen in a context where they have a high likelihood of being reimbursed. Specifically, more than 35% of all 0-5 year old children in the United States are covered by a publicly-funded health insurance program called Medicaid. Since its inception, Medicaid has mandated that all eligible children receive early preventive health care through the Early and Periodic Screening Diagnosis and Treatment (EPSDT) program, but this has never been achieved. A national review of EPSDT revealed that of the 22.9 million children eligible for these services, only 36% received a medical screen and only 13% received a hearing screen (Olson, Perkins and Pate 2007). Olson et al. also noted that the poorest children and those from minority families (who are the children most likely to acquire hearing loss during early childhood) were disproportionately less likely to receive these services.

Another problem has been identified when children are screened for hearing in their health care provider's office. In one recent study, nine pediatric practices were provided with equipment and staff to do hearing screening during well-child visits for 3-19 year old children. Of the 1,061 children screened, 10% failed. Of these, 59% failed to return for follow-up testing, indicating how difficult it is to get health care providers and families to follow-up when a child fails the hearing screening test (Halloran, Wall, Evans, Hardin and Wooley 2005).

Despite such challenges, there are examples of programs that have successfully screened children for hearing loss during the early childhood years. In one such study, young children in Head Start programs were screened for hearing using otoacoustic emissions (OAE) technology. Of the 3,486 children screened, 95% passed and 5% (183 children) were referred for a diagnostic evaluation. Of the 119 children who completed a diagnostic evaluation (64 children or 35% were lost to follow up), six had a permanent hearing loss (a prevalence of almost two per 1000), and 74 more had a chronic fluctuating conductive hearing loss that had not previously been detected or treated (Eiserman et al. 2007). Of the six children identified with permanent hearing loss, two were never screened as newborns, two had failed the newborn hearing screening test and failed to return for follow-up testing, and two had passed the newborn hearing screening test. These results demonstrate that OAE-based hearing screening of young children can be practical and effective for identifying children with late-onset hearing loss, as well as finding children who miss their newborn hearing screening test or are lost to follow-up. For early childhood hearing screening to be effective though, there must be appropriate training, use of a sensible protocol and audiologic support.

What is the Target of Newborn Hearing Screening?

To reduce the number of newborns who need follow-up testing after hearing screening in the hospital, many screening programs have begun using a two-stage protocol in which newborns are screened first with otoacoustic emissions (OAEs), and no additional testing is done for those who pass. Newborns who fail the initial OAE are screened a second time with automated auditory brainstem response (A ABR). Those who pass the A-ABR are considered to have normal hearing, even though they failed the initial OAE test.

A recent multi-center study by Johnson et al. (2005) was done to determine how many infants who failed the OAE and passed the A-ABR had permanent hearing loss at 9 months of age. From a birth cohort of 86,634 infants screened at seven geographically dispersed birthing centers using a two-stage OAE/A-ABR hearing screening protocol, 1,524 infants who failed the OAE but passed the A-ABR were enrolled in the study. Diagnostic audiologic evaluations were completed for 64% of the enrolled infants when they were an average of 9.3 months of age. The study found that 21 infants (30 ears) who had passed the newborn A-ABR hearing screening had permanent hearing loss when the child was 8–12 months of age.

When the results for those infants who failed the OAE but passed the A-ABR screening were combined with those of the infants who failed the OAE and failed the A-ABR, it was determined that the incidence of permanent hearing loss in this cohort of 86,634 newborns was 2.37 per 1000 (this incidence is a little lower than what would be expected in the general population because only one of the seven participating centers enrolled children from the neonatal intensive care unit). Alarmingly, 23% of the infants with permanent hearing loss in this cohort would have been missed if babies who

failed the OAE but passed the A-ABR had been considered to have normal hearing and were not followed because they passed the A-ABR. Most (71.4%) of the infants with hearing loss who failed the OAE but passed the A-ABR screening test had mild hearing loss.

The results of this study have important implications for newborn hearing screening programs. First, program administrators should carefully evaluate what screening protocol and equipment is best for their situation and objectives. In particular, they should explicitly consider whether they want to detect children with mild hearing loss. In making such decisions, it is important to remember that this is not an issue of whether or not to use A-ABR hearing screening equipment. Instead, it is an issue of how the stimulus presentation for that equipment is set. If a different intensity stimulus had been used (e.g., a 25 dB nHL click stimulus instead of the 35 dB nHL stimulus that was used in this study), fewer children with mild hearing loss would have been missed.

Second, parents and health care providers need to be reminded frequently that passing a newborn hearing screening test does not guarantee that the child does not and will not have a permanent hearing loss. Third, hospital-based newborn hearing screenings are not sufficient to detect all permanent hearing loss that occurs during childhood. In addition to making hospital-based screening programs as efficient as possible, public health officials should consider the pros and cons of doing systematic hearing screening during the early childhood years in day care, preschool programs, or well-child visits in health care provider offices.

Shortage of Appropriate Early Intervention Programs

As the age of identification for children with hearing loss has decreased and cochlear implants and digital hearing aids have become more widely available, the choices that parents are making about how they want their deaf children to be educated is also changing. Approximately 95% of children with hearing loss are born to hearing parents (Mitchell and Karchmer 2004). Given recent evidence about the ability of children with hearing loss who received early cochlear implants and high-quality early intervention to achieve at similar levels as their hearing peers (Geers 2004; Cheng et al. 2000), it is not surprising that increasing numbers of parents are choosing programs that focus on teaching children with hearing loss to listen and speak, rather than sign language-based programs, which historically is how many children with hearing loss were educated. For example, Brown (2006) compared the choices made by parents of children with hearing loss in North Carolina in 1995 and again in 2005. North Carolina has a well-developed system of early intervention programs for children with hearing loss that includes a full range of auditory/oral and sign language-based options. In 1995, 40% of families chose auditory/oral options compared to 60% who chose sign language-based options. In 2005, 85% of families chose auditory/oral options compared to 15% who chose sign language-based options. Such a dramatic change over a ten-year period has important implications for how early intervention program providers are trained.

Currently, there are about 70 university-based programs for preparing teachers of the deaf or other professionals to work with children with hearing loss. Based on information contained in the 2004 and 2005 issues of *The American Annals of the Deaf*, combined with information about faculty publications, curriculum, the placement of graduates, and program websites, these programs were classified by White (2007) as to whether the primary emphasis was on sign language or listening and spoken language. The vast majority of these programs focus primarily on sign language-based options. In fact, of all graduates from teacher of the deaf programs in 2004, only 8% were from programs that focused primarily on listening and spoken language.

Administrators of early intervention programs for children with hearing loss are in a difficult position. Most parents, when they are given an option, choose listening and spoken language based programs. However, the vast majority of teachers graduating from university-based deaf education programs are trained primarily in sign language-based options. Adjusting the mix of options in a way that provides families with the choices they would like to have and still maintaining a staff of well-trained teachers is difficult.

Serving Children who Live in Rural and Remote Areas

One of the reasons that many young children with hearing loss do not receive the early intervention services they need is that deafness is a relatively low-incidence condition. Consequently, many children with hearing loss live a great distance from the specialized services they need and there are often few children with hearing loss living in the same area, making it difficult

for many educational systems to find appropriately-trained people to deliver services.

A potential solution for this problem is to use two-way videoconferencing to provide early intervention services to children with hearing loss who live in rural or remote areas. As telecommunication technologies have improved and costs have declined, many people have become convinced that tele-medicine programs enable the provision of high-quality health care in situations in which it is difficult or unnecessarily expensive to have the health care provider and the patient in the same room at the same time (Wooton 2001; ASHA 2009; see also Campbell and Hyde in this volume). Many people believe that the expanded use of tele-medicine solutions can be used to provide high-quality care, save money through improved care management and coordination, and reduce the costs of delivering services (Hakansson and Gavelin 2000).

A few small-scale implementations of tele-medicine solutions have been done to explore whether this approach would be appropriate for providing services to infants and young children with hearing loss – hereafter referred to as "tele-intervention" (McCarthy, Munoz and White 2010). Early intervention providers who have participated in these tele-intervention programs have noted that parents seem to acquire skills more rapidly than in a traditional face-to-face model. In a face-to-face session, the early intervention specialist may regard the child as the primary participant and engage more often in modeling activities and strategies directly with the child and involving the parents only occasionally. In a tele-intervention setting, the roles shift because the early intervention specialist has limited physical access to the child and must now regard the parents as the primary participants. This shift seems to change the focus of the session from teaching the child to coaching the parent(s) in implementing appropriate educational activities with their child. Anecdotal evidence has also suggested increased participation by fathers and other family members, as well as fewer cancellations by families. This increased level of engagement is probably attributable to greater ease of attendance and flexibility of scheduling (McCarthy et al. 2010).

Physician Knowledge

Moeller, White and Shisler (2006) recently collected surveys from a national sample of 1,968 physicians to evaluate their attitudes, practices, and knowledge related to newborn hearing screening and intervention. Even though there is broad agreement about the central role that physicians should play in ensuring that congenital hearing loss is identified early and treated appropriately, the results of this survey showed that many critical gaps exist. For example, 53% of the respondents did not know that infants who were 3 months of age or younger could be fitted with hearing aids, and 18% thought it necessary to wait until the child was 12 months of age or older before a hearing aid could be fitted.

There is widespread agreement that all infants and young children who are diagnosed with permanent hearing loss should also be seen by an otolaryngologist, a geneticist, and an ophthalmologist (JCIH 2007). The baby's primary health care provider is in the best position to help families obtain such services from an appropriate provider. However, in this survey of physicians, the need for a referral to a geneticist was recognized by only 11% of pediatricians, 3% of family physicians, and 22% of otolaryngologists. Furthermore, the need to refer to an ophthalmologist was recognized by only 1% of pediatricians, none of the family physicians, and 7% of otolaryngologists.

In cases where hearing loss is so severe that hearing aids cannot provide sufficient amplification for the acquisition of spoken language, physicians should be prepared to discuss information about cochlear implants with families. However, almost 50% of respondents were incorrect about the type and level of hearing loss that would make a child an appropriate candidate for a cochlear implant, and almost 70% reported a lack of confidence in discussing this surgical procedure with families of such children.

These examples clearly demonstrate the need to better educate physicians about currently recommended practice for infants and young children with hearing loss. Armed with appropriate knowledge and skills, physicians can be a valuable resource to families.

Conclusion

Much progress has been made in the last 20 years related to early hearing detection and intervention, but there is still much to do if we want all infants and young children to be identified early and provided with appropriate audiological, medical, and educational intervention programs that will enable them to reach their full potential. First, continuing effort must be devoted to global expansion of universal newborn hearing screening programs based on physiological measures. While

we continue working to improve and expand hospital-based newborn hearing screening programs, we must also pay attention to other opportunities to improve outcomes for infants and young children with hearing loss. Focusing on reducing loss to follow-up from newborn hearing screening programs, ensuring that appropriate early intervention programs are available to children identified with hearing loss, educating various stakeholders about recent advances in hearing screening and intervention, using more effective screening protocols, and expanding the settings where hearing screening for infants and young children is done are some of the challenges that need to be addressed.

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Appendix A: Status of Newborn Hearing Screening in Various Countries Based on Published Reports

Countries Screening 90% or more of Newborns						
Country	Annual Births	Published Reports		Country	Annual Births	Published Reports
1. Austria	76,000	64		5. Slovakia	55,000	20
2. Netherlands	185,000	19,25,60		6. United Kingdom	743,000	12,39,66
3. Oman	61,000	22,45,66		7. United States of America	4,399,000	65,66
4. Poland	372,000	57,67				
Countries Screening 25-89% of Newborns						
1. Australia	267,000	54		6. Philippines	2,236,000	45,66
2. Belgium	119,000	61,62		7. Russia	1,545,000	66
3. Canada	353,000	66		8. Singapore	37,000	21,33,45
4. Germany	666,000	66		9. Taiwan	205,000	29,30-32,45
5. Ireland	69,000	2,37				
Countries with Pilot Programs: Screening Less than 25% of Newborns						
1. Albania	46,000	17		24. Iran	1,388,000	45
2. Argentina	689,000	14		25. Israel	140,000	5
3. Bahamas	6,000	44		26. Japan	1,034,000	1
4. Bangladesh	3,430,000	66		27. Jordan	157,000	5,45
5. Benin	342,000	43		28. South Korea	452,000	66
6. Brazil	3,105,000	6,45,66		29. Kuwait	52,000	4
7. Bulgaria	73,000	53		30. Luxembourg	5,000	48
8. Chile	251,000	13,45		31. Malaysia	551,000	3,36,45
9. China	18,134,000	40,55,60,63,66,69		32. Mexico	2,049,000	13,45,68
10. Costa Rica	75,000	13		33. Nepal	732,000	66
11. Columbia	918,000	13		34. Nigeria	6,028,000	45,46,66
12. Cote d'Ivoire	722,000	58		35. Pakistan	5,337,000	45
13. Croatia	42,000	51		36. Panama	70,000	13
14. Cuba	118,000	50,52		37. Qatar	15,000	44
15. Cyprus	10,000	16		38. Saudi Arabia	591,000	45
16. Denmark	62,000	32,35		39. South Africa	1,091,000	45,56
17. Egypt	2,015,000	26		40. Spain	491,000	47,59
18. France	752,000	23,28,42		41. Sri Lanka	365,000	66
19. Greece	107,000	24		42. Switzerland	73,000	9
20. Guatemala	453,000	13		43. Thailand	977,000	66
21. Hong Kong	53,000	45		44. Tunisia	164,000	44
22. India	26,913,000	27,38,45,66		45. Turkey	111,000	45
23. Italy	546,000	8,10,11,14,34		46. Uruguay	50,000	13

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