Introduction

In the past decade, there has been considerable progress in the early identification and remediation of hearing loss. The widespread implementation of Universal Newborn Hearing Screening (UNHS) programs in conjunction with advances in otoacoustic emissions (OAEs), frequency-specific ABRs, and advanced signal processing for hearing aids have facilitated the early identification and remediation of hearing loss. In turn, these advances have improved the lives of hearing-impaired children and their families. Ironically, however, these improvements have brought new challenges in our field. The goal of this chapter is to discuss these new challenges, review relevant research, and suggest areas where further research studies are needed. Specifically, this chapter will address how advances in newborn hearing screening, diagnostic evoked potentials, and signal processing for hearing aids have created new challenges for audiologists, early interventionists, hearing aid manufacturers, and families of children with hearing loss.

Progress Area I: Universal Newborn Hearing Screening

UNHS has quickly become the standard of care throughout the United States and in numerous countries around the world. The ability not only to identify hearing loss early in life, but also to provide early intervention and amplification has literally changed the lives of children with hearing loss. While only 5% of babies born in the U.S. were screened for hearing loss in 1993, currently 95% of all newborns are screened prior to hospital discharge, and 47 states plus the District of Columbia have UNHS programs (NCHAM 2006). In a study conducted in Rhode Island, Vohr, Carty, Moore and Letourneau (1998) reported that, following the implementation of UNHS, the mean age of identification in the state decreased from 8.7 months to 3.5 months and the age at amplification declined from 13.3 months to 5.7 months. Furthermore, the ability to intervene early has been shown to minimize the negative impact of sensorineural hearing loss (SNHL) on speech and language learning (Mayne, Yoshinaga-Itano and Sedey 2000; Mayne, Yoshinaga-Itano, Sedey and Carey 2000; Moeller et al. 2007a,b).

Despite these successes, infants with borderline normal hearing and/or high-frequency hearing loss are still missed (Gorga, Neely and Dorn 1999). While increasing the stringency of criteria would improve the detection of hearing loss in these groups, it also would increase the number of overall referrals (false positives). In turn, the cost for follow-up testing would increase (Gorga, Preissler, Simmons, Walker and Hoover 2001) and the confidence in UNHS programs would likely decrease. A related concern is the fact that when the “referral rates” in UNHS programs are high, parental anxiety increases and physician confidence in these pro-
grams decreases. To complicate the situation further, physicians are often reluctant to act on parental concerns for hearing loss if their child initially passed UNHS.

In a recent study of physician knowledge regarding childhood hearing loss and UNHS, Moeller, White and Shisler (2006) sampled 1968 primary care physicians across the U.S. and Puerto Rico regarding: (1) the Joint Commission on Infant Hearing (JCIH) Screening Guidelines (2007); and (2) the ages at which re-screening following UNHS, a definitive diagnosis of hearing loss, fitting of hearing aids, and early intervention should be determined/initiated. Table 1 shows the responses from pediatricians (N = 1153) and family practice physicians (N = 532) regarding the current JCIH guidelines. While both groups seemed to be aware that meningitis and/or a family history of hearing loss would put a child at risk for hearing loss, and the majority were also aware that cytomegalovirus (CMV) posed a risk, almost half of the respondents did not know that a NICU stay of > 48 hours was a risk factor. Also from Moeller et al. (2006), Table shows responses from these same physicians to a questionnaire regarding the age at which re-screening, a definitive diagnosis of hearing loss, hearing aid fitting, and a referral for early intervention should occur. The shaded cells denote optimal answers from an audiological perspective. On the positive side, 88% of respondents knew that re-screening should occur in the first 3 months of life and 70% reported that early intervention for children with confirmed hearing loss should begin by 3 months of age. However, nine percent of respondents believed that a diagnosis of permanent sensorineural hearing loss (SNHL) could not be confirmed until after 12 months. Interestingly, 38% of respondents thought that the initial hearing-aid fitting could occur prior to one month of age (which, for reasons discussed later, is overly optimistic) and 18% reported that hearing aids should not be fitted until after 12 months of age. It appears from this research that the two groups of physicians who are most likely to provide primary care to infants and young children are not consistently well-informed regarding current best practice guidelines. The overall success of UNHS and early intervention programs depends on the provision of timely referrals for diagnostic and intervention services, as well as support from physicians. Parents rely heavily on advice from their physicians regarding the “next steps” when their child does not pass newborn hearing screening. It is essential that physicians be well-informed about the process of UNHS, the appropriate follow-up procedures, audiological services, and early intervention. The results of this study suggest that more work is needed to ensure that physicians are well prepared to address the concerns of families whose children do not pass UNHS.

Table 1. Responses from 1153 pediatricians and 532 family practice physicians regarding risk factors for hearing loss. Adapted from Moeller et al. (2006).

<table>
<thead>
<tr>
<th>Risk Factors for Late Onset Hearing Loss</th>
<th>2007 JCIH Guidelines</th>
<th>% of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition</td>
<td>% of Pediatricians</td>
<td>% of Family Practice</td>
</tr>
<tr>
<td>Meningitis</td>
<td>99%</td>
<td>97%</td>
</tr>
<tr>
<td>&gt;48 h. NICU stay</td>
<td>48%</td>
<td>58%</td>
</tr>
<tr>
<td>History of CMV</td>
<td>88%</td>
<td>78%</td>
</tr>
<tr>
<td>Family Hx of Childhood HL</td>
<td>94%</td>
<td>90%</td>
</tr>
</tbody>
</table>

New Challenge: Education of Parents, Nurses and Physicians

There is a crucial need to educate healthcare providers regarding the process of UNHS, optimal referral rates, and appropriate protocols for infants who fail UNHS. Physicians also need to gain a better understanding of the consequences of various types and degrees of hearing loss (e.g., mild, unilateral and high-frequency hearing loss, conductive hearing loss, and auditory neuropathy). They need to understand that the consequences of congenital hearing loss are fundamentally different from a hearing loss of similar type and degree acquired later in life. Fortunately, several websites provide information on UNHS programs, diagnostic audiology, and early intervention for children with varying degrees of hearing loss (e.g., babyhearing.org; infanthearing.org; raisingdeafkids.org; handsandvoices.org).

Progress Area II: Frequency-Specific Evoked Potentials (ABR, ASSR)

A well-designed and implemented UNHS program is of little value without an objective method to diagnose accurately the degree, type, and configuration of hearing loss. By 2 months of age, infants are able to recognize and distinguish their mother’s voice from other talkers (DeCasper and Fifer 1980). By 6 months they can distinguish the sounds and rhythmic patterns of their native language from other languages (Werker and Tees 1984; Jusczyk and Luce 2002), and by 7 months they can generalize across talkers despite differences in gender, fun-
damental frequency, and formant frequencies (Kuhl 1983; Houston and Jusczyk 2000). By 12 months, first words emerge (Bloom 2000). These remarkable accomplishments support the notion that the auditory skills learned early in life lay the foundation for later speech, language and psychosocial development. As such, it is generally assumed that early intervention is critical to minimize the negative consequences of hearing loss.

It has been well established that behavioral methods cannot be used to determine auditory thresholds reliably for children less than 6 months of age (Widen 1993). Thus, to provide optimal early amplification and intervention, objective measures are needed. Early attempts were based on click-evoked auditory brainstem responses (ABRs), but these measures could not provide the frequency specificity needed to determine individual frequency-gain characteristics for amplification devices. Tone-burst ABRs (and tones in notched noise) have been shown to provide valid and reliable measures of auditory thresholds as a function of frequency (Stapells, Gravel and Martin 1995; Gorga, et al. 2006). It has been shown that Auditory Steady-State Responses (ASSR) can provide similar threshold data (Picton, Dimitrijevic, Perez-Abalo and Van 2005).

In addition to quantifying the degree of hearing loss, frequency-specific evoked potential thresholds can be used to determine target-gain values prior to the hearing aid fitting. These target-gain values can be used in conjunction with probe-microphone measures to verify the audibility of speech across both frequency and a range of input levels for each child.

Although click-evoked ABR measures do not have the frequency specificity to estimate degree and configuration of hearing loss, they can be used to differentiate quickly between sensorineural hearing loss and auditory neuropathy/dys-synchrony (AN/AD). Specifically, a no response ABR and/or abnormal waveform morphology in the presence of cochlear microphonic and/or OAEs is indicative of AN/AD. Because ASSR measures do not produce a waveform, this test cannot be used to identify children with auditory neuropathy. For this reason, the Year 2007 Position Statement from the Joint Commission on Infant Hearing has specified that “there is insufficient evidence for the use of the ASSR as the sole measure of auditory status in newborn and infant populations.”

New Challenge: Early Management of Infants with Hearing Loss

Despite the fact that all of the necessary tools are in place to screen, re-screen, and objectively measure degree and configuration of hearing loss for infants who do not pass UNHS, there is no consensus regarding the early management of children with borderline normal, mild, unilateral, low-frequency, or high-frequency hearing loss. For these children, audiologists and physicians often have differing views regarding the need for intervention. Studies have shown that children with minimal hearing loss exhibit problems and/or delays in speech perception (Elfenbein, Hardin-Jones and Davis 1994), vocabulary development (Davis, Shepard, Stelmachowicz and Gorga 1981), language, educational, and psychosocial development (Davis, Elfenbein, Schum and Bentler 1986), morphological development (Elfenbein et al.1994; Norbury, Bishop and Briscoe 2001), advanced grammatical skills (Friedmann and Szterman 2006), and social communication and self esteem (Davis et al. 1986; Bess,
Dodd-Murphy and Parker 1998; Wake, Hughes, Poulakis, Collins and Rikards 2004). In addition, Pendergast, Lartz and Fiedler (2002) reported that the presence of a child with hearing loss in the home tends to increase family stress. Despite evidence supporting the need for intervention with this group of children, parents are often reluctant to acknowledge the need for intervention and/or amplification because these children will generally hear many sounds in their environment.

Another group that has emerged due to advances in early identification are children with profound hearing loss (i.e., no response ABR) who are identified at birth and deemed likely to receive a cochlear implant within the first year of life. The optimal management of these children has not been clearly established. Is it appropriate to fit these children with hearing aids? Should they receive one or two hearing aids? When the ABR shows no response, how should the hearing aids be set? Who should pay for hearing aids? Should sign language be implemented until the child is implanted? These are difficult and complex issues that raise practical, ethical, and financial questions for parents, audiologists, and early interventionists.

Children with suspected AN/AD are another group that has emerged as a consequence of UNHS programs and appropriate follow-up testing. These children generally pass OAE screening but exhibit no ABR or an ABR with abnormal morphology. Research has shown that some of these children will ultimately do well with hearing aids, while others will be cochlear implant candidates (Rance 2005). Madden, Rutter, Hilbert, Geinwald and Choo (2002) reported that 50% of their cohort of children with auditory neuropathy (N = 18) showed improvements in auditory thresholds within the first year of life. These statistics, and the fact that some children with AN/AD do well with hearing aids, would suggest caution when considering children with AN/AD for early implantation.

Finally, there is no consensus on how early in life children with confirmed permanent hearing loss should be fitted with hearing aids. Should this timeline vary by degree and type of hearing loss, the family situation, and/or parental wishes? As mentioned previously, auditory development in normal-hearing children clearly indicates that many skills are learned within the first several months of life. While these accomplishments suggest that early intervention may be critical, a multitude of practical issues also must be considered.

For example, reliable frequency-specific evoked potential thresholds are needed to determine target frequency-gain characteristics. Factors such as middle-ear disease and concomitant medical problems can complicate the ability to obtain objective threshold measures in the first few months of life. Infant ear canals may not be large enough to accommodate earmolds. Early parental frustration with acoustic feedback, frequent earmold remakes, and hearing-aid retention may have long-term consequences in terms of parental compliance with intervention strategies. Ongoing support from audiologists and early interventionists is critical in order to ensure consistent hearing aid use.

**Progress Area III: Hearing Aid Signal Processing**

Numerous advances in both hearing aid ergonomics and advanced signal processing have taken place in recent years. The size and shape of behind-the-ear hearing aids have evolved to accommodate the unique needs of infants and young children. Numerous devices have been developed to improve retention and prevent loss of hearing aids. More importantly, several advances in signal processing have provided audiologists with options that have the potential to improve auditory access for children with hearing loss.

**Directional Microphones**

The sophistication of directional microphones has improved dramatically in recent years. The goal of this technology is to improve the signal-to-noise ratio (SNR) for sounds arriving from 0° azimuth. This technology may be accessed by manual selection of this option or by the use of an adaptive algorithm that is designed to optimize automatically the SNR in complex environments. One of the first studies of the use of directional microphones with children was conducted by Gravel, Fausel, Liskow, and Chobot (1999). In this laboratory study, the benefit of directional microphones was evaluated in ten 4–6- and ten 7–11-year-olds. Results revealed a benefit of 4.7 dB relative to an omni-directional microphone condition which is similar to the benefit reported in studies with adults (Bentler, Palmer and Mueller 2006). In addition, the youngest children (4–6 years) required a more advantageous SNR to achieve the same speech perception performance as older children (7–11 years). Kuk, Kollofski, Brown, Melum and Rosenthal (1999) assessed both speech recognition in noise and subjective listener preferences in 20 school-aged children wearing digital directional hearing aids in comparison to their own analog omni-directional hearing aids. Results revealed improved speech recognition scores at multiple presentation levels with the directional
hearing aids and a subjective preference for the directional microphone.

To date, no systematic studies have been conducted with children less than 4 years of age, so it is not clear at what age this technology should be considered. An obvious practical issue is safety. Because devices with fixed directional microphones attenuate sounds arriving from the rear, it is possible that children wearing these hearing aids may not hear important warning signals (e.g., an approaching vehicle).

Another important factor is children’s understanding of communication principles. Since young children do not necessarily maintain eye contact with conversational partners, in some situations they may actually hear less with directional than with omni-directional microphones. A classroom study by Ricketts (2007) supports this concern. He found that, even in a structured classroom setting, school-age children do not necessarily direct their attention toward the speaker.

Finally, it has been well established that young normal-hearing children typically learn not only through direct teaching, but also from “overhearing” the conversations of others (see Chapter 1 by Moeller in this volume). In fact, pronouns (i.e., he, she, they) are almost exclusively learned via overhearing. Similarly, slang and colloquial expressions typically are learned via listening in on the conversations of others. Because, by design, directional microphones reduce sounds arriving from the rear or from a specific azimuth in the case of adaptive directional microphones, it is likely that this form of “input” via incidental listening would be diminished. As mentioned previously, no studies have been conducted to address the developmental age at which directional microphones (either fixed or adaptive) should be considered. Conventional wisdom might suggest that these devices would be appropriate as soon as a child is mature enough to understand communication principles and to switch appropriately between omni-directional and directional microphones in different situations. However, controlled studies in both laboratory and typical environments are needed to understand fully the benefits and possible detriments that may be expected when using this type of technology with young hearing-impaired children.

Frequency Compression/Transposition

The initial application of this technology was intended to improve audibility for individuals with severe-to-profound high frequency hearing loss where traditional amplification could not provide adequate gain. These early processing schemes were designed to “shift” the high frequency components of speech to lower frequencies, typically by a fixed value in Hz (Ling 1968; Beasley, Mosher and Orchik 1976; Reed, Schultz, Braida and Durlach 1985; Posen, Reed and Braida 1993). These early attempts met with limited success largely due to complications such as shifts in voice pitch, alterations in the time course of acoustic events, and unnatural sound quality.

The subsequent use of proportional frequency compression (using a fixed ratio) helped to preserve the normal frequency relations between the spectral components of speech, thus minimizing the problems described above. With proportional frequency compression, the entire bandwidth of speech is compressed to lower frequencies and the spectrum is narrowed. The first commercially available device (Transonic Body Aid) was introduced in 1991. This device was designed primarily for individuals with minimal residual hearing sensitivity (i.e., corner audiograms). In 1998, a BTE hearing aid (AVR, Impact DSR 675) was introduced, followed by a smaller BTE and an in-the-ear device in 2000. The most recent versions (DSP ImpaCt XP and the Nano XP) were introduced in 2004 and include directional microphones, noise reduction, as well as enhancements to the speech processing features. The early work in this area showed mixed results. In addition to the specific signal processing schemes, factors such as small N studies, speech materials, acclimatization, focused training, and degree/configuration of hearing loss may have influenced outcomes in ways that were not clearly understood.

Several other manufacturers (Phonak, Widex) have developed devices that are commercially available. Because current technology is much more sophisticated than earlier devices, the results of many prior studies are not likely to be predictive of current performance (see Chapter 13 by Scollie et al. in this volume for a review). Several more recent studies are worth noting, however. Miller-Hansen, Nelson, Widen and Simon (2003) reported results from a study conducted with 78 children (1.3–21.6 years). In a subgroup of children (N = 16) who were able to perform a word recognition task (PBK words), the mean improvement over their conventional hearing aids was 12%. However, the greatest improvements in performance (relative to conventional hearing aids) were achieved by those children with hearing loss in the severe range (mean improvement of 24%). Simpson, Hersbach and McDermott (2005) evaluated a prototype frequency
compression device in 17 adult subjects (mean age of 56 years). Stimuli were CNC words spoken by a female. Data were analyzed in terms of percent correct phonemes, fricatives, consonants, and vowels. Eight subjects showed a significant increase in phoneme scores with frequency compression (FC), eight showed a decrease in performance, and one showed no change. An analysis of results in terms of acoustic features (manner, place, voicing, sonorance, and frication) revealed that this form of FC improved the perception of place and frication. In a second study, the perception of CNC words and VCV syllables in quiet was assessed for seven adults with steeply-sloping hearing losses (Simpson, Hersbach and McDermott 2006). While the mean data failed to show a statistically significant difference between FC and conventional processing, one subject showed a significant improvement in performance while two others showed significant decrements. In addition, the SNR corresponding to 50% performance for CUNY sentences was measured with and without FC for five participants, but no statistically significant differences were observed. Although not suggested by these investigators, these results raise several questions regarding candidacy for FC. In this study, the median age of subjects was 57 years. It is possible that older subjects may have more difficulty adjusting to novel signal processing than children or younger adults. Furthermore, their subjects had profound hearing loss in the high frequencies and five of the seven subjects had thresholds > 80 dB SPL at 1000 Hz, while the remaining two had 1000 Hz thresholds of 50 and 65 dB HL. With this degree of hearing loss, it is possible that even with FC, reduced signal audibility may have limited performance.

Results from a study of the effects of bandwidth on various aspects of auditory performance illustrate this point (Stelmachowicz, Lewis, Choi and Hoover 2007). Figure 1 shows auditory thresholds for the 24 children with hearing loss (6–14 years) who participated in this study. All children had thresholds < 65 dB HL at 6 and 8 kHz. Figure 2 shows the effects of stimulus bandwidth on the perception of PBK words presented in noise (+10 dB SNR) as a function of age group. While there was considerable variability across subjects, the effects of bandwidth were statistically significant. Figure 3 shows the distribution of scores with number of subjects on the y axis and the percent improvement on the x axis. These results indicate that four children showed a slight decrement in performance at the wider bandwidth, four showed no change, and 16 showed benefits ranging from 4 to 44%.

**Multi-Memory Hearing Aids**

Virtually all hearing aids manufactured today have multi-memory capabilities, thus facilitating the ability quickly to engage special features such as noise reduction, frequency compression/transposition, and directional microphones. Although most studies have been
conducted with adults, Christensen (1999) investigated the ability of 9–14-year-old children to use multiple-memory devices. Results indicated that these children were willing and able to switch memories and that they reported subjective benefit from being able to do so. While no studies of subjective or objective benefit in younger children with hearing loss have been published, there are some obvious applications of this technology for this population. For children with fluctuating hearing loss due to middle-ear pathology or AN/AD, it may be useful to program a memory with increased gain allowing parents or caregivers the ability to easily compensate for threshold shifts when necessary. Parents and/or older children may also find this option useful in order to compare the efficacy of various signal processing schemes (e.g., noise reduction, directional microphones, feedback control) in different environments. When considering this option with young children, the responsible parties must be well-counseled regarding when and why to switch between memories.

Single Microphone Noise Reduction

Although the efficacy of current directional microphone technology has been clearly established (Wouters, Berghe and Maj 2002; Bentler et al. 2006; Palmer, Bentler and Mueller 2006), their effectiveness is diminished in some situations (e.g., reverberant environments). Thus, alternative approaches to noise reduction have been developed. In single-microphone noise reduction (NR), a complex algorithm is used to detect the frequency regions(s) where noise is present and to reduce the noise in specific frequency bands accordingly. When characteristics of the interfering noise can be clearly defined (e.g., fan, computer noise), signal processing algorithms can easily be developed to improve the SNR (Levitt 2001). In hearing-aid applications, however, specific knowledge of the spectral characteristics of competing noise is rarely available. The most common methods of NR use some variation of either spectral subtraction or an assessment of SNR in each band followed by gain reduction. While the ability of these systems to detect the presence of noise is good, separating speech from noise without altering the signal of interest is more challenging. Studies with adults have shown significant improvements in speech perception when the noise is restricted to a narrow frequency region (Van Dijkhuizen, Festen and Plomp 1991; Rankovic, Freyman and Zurek 1992). When the spectra of the target signal and noise are similar, however, most studies have failed to show improvements in speech perception (Levitt, Neuman and Sullivan 1990; Levitt et al. 1993; Boymans and Dreschler 2000; Alcantara, Moore, Kuhnel and Launer 2003). While some studies have shown that NR neither impairs nor improves speech recognition, Jamieson, Brennan and Cornelisse (1995) reported that NR reduced test performance when stimuli were nonsense syllables. This suggests that noise reduction may actually degrade the speech signal for low-context materials. Because of the inherent redundancy of conversational speech and the use of top-down processing by adults and older children, any signal degradation caused by NR may have little influence on speech perception for adults with acquired hearing losses, but may be detrimental to infants and young children who are developing speech and language skills.

It is important to recognize that, although most studies of single microphone NR have failed to show objective improvements in speech perception, hearing impaired (HI) adults often report improved comfort and/or reduced listening effort with this type of processing (Jamieson et al. 1995; Boymans and Dreschler 2000; Walden, Surr, Cord, Edwards and Olson 2000; Ricketts and Hornsby 2003, 2005; Mueller, Weber and Hornsby 2006). If similar effects were to occur for children, it is possible that reduced listening effort might
improve attention to specific tasks. To date, however, no studies have been published regarding the effects of single-microphone NR circuitry for HI children. Such an investigation is currently in progress at Boys Town National Research Hospital. The overall goal of this study is to assess the effects of NR on the perception of nonsense syllables, words, and sentences in children (6–10 years of age). It is believed that the use of a hierarchy of speech materials will allow us to interpret results in the context of early auditory skill development (i.e., the ability to use phonotactic, lexical, semantic, and syntactic information). The goal is to determine the age at which NR would be an appropriate signal-processing option. In this study, children wore binaural digital hearing aids with NR as an option. Speech stimuli were presented in the sound field in a background of speech-shaped noise at SNRs of 0, 5, and 10 dB. Figure 4 shows preliminary results from eight children (8–10 years) with mild-moderate sensorineural hearing loss. As can be seen, the mean data suggest that NR neither improves nor impairs the ability to perceive any of these speech materials at any of the three SNRs. A similar analysis in terms of acoustic features (i.e., place, manner, voicing) showed similar findings. These preliminary results are encouraging in that they seem to imply that, for this small group of HI children, NR did not appear to degrade the speech signal. However, it is important to note that similar data have not yet been collected for younger children. It is possible that there may be an interaction between NR and age. Specifically, it remains to be seen whether younger children may be more negatively affected by this type of processing. In addition, it is important to point out that the inter-subject variability to date has been quite large (particularly for nonsense syllables and words) with some subjects showing improvements with NR as large as 27% and others showing decrements of 33%. Factors such as degree and configuration of hearing loss and consistency of hearing-aid use will ultimately be explored in an attempt to understand these individual differences.

**FM Systems**

Despite the known negative effects of noise, distance and reverberation on the perception of speech in common environments, the use of FM systems with hearing-impaired children in non-academic environments is still relatively rare. Moeller, Donaghy, Beauchaine, Lewis and Stelmachowicz (1996) conducted a 2-year longitudinal study of FM system use in non-academic settings. Participants were ten children with mild-to-severe sensorineural hearing losses. All children were enrolled in the same auditory-oral preschool where they wore personal body-worn FM systems. For the purposes of this study, five of these children were selected to wear their FM systems in non-academic settings, while the other five children, the hearing aid (HA) group, used their personal hearing aids outside the classroom. Parents of children in the FM group were instructed in the proper use of FM technology. At the onset of the study, language samples were obtained from all children to establish a baseline and were repeated thereafter at 6-month intervals to assess language development. Language samples were independently transcribed by two experimenters and subsequently analyzed using Systematic Analysis of Language Transcripts (SALT) and Developmental Sentence...
Scoring (DSS) procedures (Miller and Chapman 1991; Hughes, Fey and Long 1992). At the end of the 2-year study, the average change in language age was 36.3 months for the FM group and 29.5 months for the HA group, but large individual differences were observed in both groups.

Both parents and children were interviewed regarding their experiences with FM technology. Parents of children in the FM group reported that the FM system provided increased opportunities for language input in situations that would have otherwise been lost opportunities. They also reported that children were less likely to ask for clarification and that they observed an increase in their children’s willingness to participate in conversations. Other noted benefits were an increased comprehension of television programs and some use of “overheard” phrases. Parents also reported an increase in the ability to control their children’s behavior in difficult situations. However, parents and children complained of practical issues such as bulkiness and interference. Fortunately, recent advances in FM technology have diminished such problems.

Results of the children’s interview revealed that some children felt more secure when their parents wore the FM transmitter. However, evidence of inappropriate use was also noted. One child reported that he didn’t like it when he could hear his parents arguing in another room. Similar examples revealed that parents would often forget to switch appropriately between FM and hearing aid modes as necessary. Another child reported that he did not like it when his daycare worker would use his FM system to relay messages to other children on the playground (e.g., tell Johnny that his mom is here). These events occurred despite specific training in the use of FM technology with all parents.

New Challenge: Use of Advanced Signal Processing with Young Children

Considerable progress in many aspects of hearing-aid signal processing has occurred in recent years with documented benefit for adults with hearing loss. Studies addressing the application of this technology to young children are lacking. Currently there are more questions than answers. Of high importance is the fact that there is no consensus on the developmental age at which specific hearing-aid technologies should be introduced. In addition, rapid technological advances create a challenge for audiologists when selecting the first set of hearing aids for an infant. Should the first hearing aids include multiple capabilities that can be activated later? Without specific knowledge regarding the age at which directional microphones or noise reduction should be introduced, it is not possible to determine if the directional-microphone algorithms available at the initial fitting will be outdated by the time the child is old enough to use this option.

Summary

The significant progress in the early identification and management of childhood hearing loss that has taken place over the past decade has raised new issues and questions that have yet to be resolved. Studies are needed to determine the optimum manner in which to educate parents and physicians regarding UNHS and follow-up, as well as the consequences of all degrees of childhood hearing loss. In addition, protocols for the early management of children with varying degrees of hearing loss need to be developed. Finally, focused studies are needed to determine the age at which children can benefit from various forms of advanced hearing-aid signal processing.

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