12 Predictors of Success for Children With Cochlear Implants

The Impact of Individual Differences

Holly F. B. Teagle and Hannah Eskridge

Difference is of the essence of humanity.

John Hume

Cochlear implantation is an intervention for deafness that has exceeded the expectations held by those instrumental in its early, controversial development. The initial goal of sound awareness seems a meager benefit compared with the phenomenal results afforded by the state-of-the-art technology and the habilitation tools and strategies available today for persons with severe to profound hearing loss. Cochlear implantation has proven to be effective to restore auditory function and to develop audition skills necessary for normal spoken communication. In the scheme of medical interventions, it ranks high in a model of cost efficiency, with both short- and long-term financial impact (Cheng et al., 2000; Francis, Koch, Wyatt, & Niparko, 1999; Johnson & Stewart, 2004; Koch, Wyatt, Francis, & Niparko, 1997; Palmer, Niparko, Wyatt, Rothman, & de Lissovoy, 1999). The development of this medical invention coincided with an evolution in therapeutic approaches to achieve the outcomes appreciated today by both the recipients and the providers of service delivery. The combination of cochlear implantation and effective habilitation for children who are deaf has resulted in a resounding triumph for the fields of audiology, speech-language pathology, and deaf education.

In this chapter, we will review the collective knowledge gathered from 20 years of clinical experience in the use of multichannel cochlear implants for children, with emphasis on understanding the variables that lend themselves to infinite combinations of individual outcomes. We may arrive at the recommendation to pursue cochlear implantation for a child after a standardized protocol to screen, identify, diagnose, and initiate early intervention services. A standardized
Individual Differences Affecting Therapeutic Change

Protocol does not imply a homogeneous implementation of the diagnostic process and subsequent intervention, however. Children present for cochlear implantation with distinctive audiological profiles, medical conditions, and developmental characteristics. Unique composites of individual differences of each child must be recognized at every stage of therapeutic intervention, from the earliest parent session to the fitting and use of technology and the ongoing focus on developmental or remedial therapy. At every stage, children should be considered in the context of their families and their social, economic, cultural, and educational environments. This is pivotal to understanding how individual differences interface with clinical success in cochlear implantation.

For the purposes of understanding the characteristics of a client that may make him or her more amenable to therapeutic change, we will identify some of the potential sources of variability. Among them are (a) the child’s hearing history, including age at onset and age at diagnosis of hearing loss; (b) the fitting and management of assistive technology; (c) the child’s medical status and general development and personality; (d) the family’s acceptance, vigilance, and rigor in their ability to navigate and participate in the medical and educational web of services; and (e) the implementation of educational and therapeutic resources. See Figure 12.1 for a schematic perspective on the influence of various factors for success of cochlear implantation.

What does it take for a child with severe to profound hearing loss to overcome the barriers imposed by sensory deprivation and loss of access to spoken language? The combined knowledge and experience of clinicians, researchers, educators, therapists, and parents have led us to our current level of knowledge and understanding. Indeed, the 2007 Joint Committee on Infant Hearing (JCIH) Position Statement (2007) is a complete guide to the fundamentals of early management of children with hearing loss. This work is the culmination of years of effort to gain recognition for the need for a universal neonatal hearing screening, rather than screening based on selected risk factors. The principles and guidelines of this statement outline each step in the process of identifying hearing loss and implementing habilitation. Table 12.1 summarizes the key points of this statement.

One aspect of service delivery described in this document is the level of competence and commitment each professional involved in the process must possess to achieve a successful outcome for any individual child. Inherently implied, but certainly beyond the control of professionals, is a level of commitment and understanding that the family must have to seek out the professionals, embrace trust and acceptance, and then glean the benefits of their combined knowledge. And finally, implicit in this position statement is recognition by interventionists of the unique abilities and needs of the individual child and his or her family. We must acknowledge, accept, and understand the differences of each set of circumstances and characteristics of the individuals involved. However, we must also strive for the ideal if we are to be successful. When the process of identification, diagnosis and intervention varies from these guidelines that reflect the ideal management, the potential benefits of systematic, timely, accurate and effective management are lost, and variability in outcome becomes more likely.
HEARING HISTORY AND DIAGNOSIS

To begin with, each child possesses a unique hearing history: the status of the cochlea, the presence of residual hearing, and the integrity of the auditory system are distinctive features of the individual child. Consider the deaf infant who was a “preemie,” a neonatal intensive care unit (NICU) survivor, a victim of infectious disease, or a host for a combination of disorders expressed as a syndrome or a genetic condition. The anatomical and physiologic characteristics of the infant that cause deafness may also result in other developmental, cognitive, and sensory concerns. The features of an infant’s short but often complex medical history are considered to determine which protocol for hearing screening applies, as separate protocols are recommended for NICU babies versus those in the well-baby nursery. Some children have significant health concerns that make the presence of a hearing loss less of a priority for assessment. With that said, timeliness of diagnosis is a cornerstone of the 2007 JCIH Position Statement, since early diagnosis enables planning for early intervention. For either protocol, if the screening for the presence of hearing loss is positive, it is critical to maintain momentum for pursuing a full diagnosis. Although the recognized goal is diagnosis by 3 months
TABLE 12.1
Key Points of the Year 2007 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs

<table>
<thead>
<tr>
<th>Hearing screening and rescreening protocols</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Universal hearing screening should occur through an integrated and interdisciplinary system of early hearing detection and intervention.</td>
</tr>
<tr>
<td>- All infants should be screened by 1 month of age.</td>
</tr>
<tr>
<td>- Those who do not pass screening should have a comprehensive audiological evaluation at no later than 3 months of age.</td>
</tr>
<tr>
<td>- Babies admitted to the neonatal intensive care unit for more than 5 days should have an auditory brainstem response (ABR) screening.</td>
</tr>
<tr>
<td>- Children who fail screening should be referred to an audiologist for rescreening and the comprehensive evaluation.</td>
</tr>
<tr>
<td>- Rescreening should be done on both ears.</td>
</tr>
<tr>
<td>- Children readmitted in the first month of life who are at risk for HL should have a repeat screening.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diagnostic audiology evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Experienced pediatric audiologists should complete the evaluation.</td>
</tr>
<tr>
<td>- At least 1 ABR should be completed for referred children less than 3 years of age.</td>
</tr>
<tr>
<td>- Children who pass screening but have risk factors for HL should be reevaluated.</td>
</tr>
<tr>
<td>- Amplification should be fit within 1 month of diagnosis for families who choose it.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Medical evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Genetic evaluation should be offered to parents of children with HL.</td>
</tr>
<tr>
<td>- An ear, nose, and throat doctor and an ophthalmologist with pediatric experience should examine children with HL.</td>
</tr>
<tr>
<td>- All infants with or without risk factors should receive ongoing surveillance of communicative development, beginning at 2 months of age during well-child visits.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Early intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Infants with confirmed HL should receive appropriate intervention at no later than 6 months of age from expert care.</td>
</tr>
<tr>
<td>- Central specialized referral sites should be available.</td>
</tr>
<tr>
<td>- Both home-based and center-based intervention options should be offered.</td>
</tr>
<tr>
<td>- Families should have access to all technologies.</td>
</tr>
<tr>
<td>- Families should have access to all options for treatment and intervention.</td>
</tr>
<tr>
<td>- Interdisciplinary intervention should be provided from experienced professionals; programs should be family oriented and culturally sensitive.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Communication</th>
</tr>
</thead>
<tbody>
<tr>
<td>- The birth hospital and EDHI should ensure parental and medical home receipt of results.</td>
</tr>
<tr>
<td>- Parents should be provided with appropriate resource and referral information.</td>
</tr>
</tbody>
</table>
of age, the infant’s parents’ ability to understand and act on the recommendations of the screening is a source of considerable variability. Bonding with a new baby, not to mention one with potentially life-altering medical conditions, may be challenging for some parents, and that acceptance, or lack thereof, affects the efficiency and immediacy of intervention service delivery. Additional time delays may occur as the baby is rescreened before undergoing a full diagnostic battery, which requires further time and expertise.

Before we can pull something from our bag of technological wonders to begin remediation, we must define the hearing loss for each ear by frequency to the best of our ability. A combination of electrophysiological (auditory brain stem response, auditory steady state response, otoacoustic emissions, acoustic immittance1) and behavioral (behavioral observation audiometry, visual response audiometry, conditional play audiometry2) audiological measures must be used to corroborate the degree and configuration of hearing loss. Typically, diagnosis is a process, of which only a formal hearing evaluation is the final step.

### TABLE 12.1 (Continued)

- Information to parents should be presented in a culturally sensitive and understandable way.
- Individual diagnostic and habilitation information should be conveyed to the medical home and EDHI coordinator.
- Families should be made aware of all communication options and technologies so they can make informed decisions.

The goal of early hearing detection and intervention is to maximize linguistic competence and literacy development for children who are deaf or hard of hearing. The definition of hearing loss (HL) includes congenital, permanent, bilateral or unilateral, sensory, neural, and permanent conductive HL.


---

1 Auditory brain stem response and auditory steady state response are noninvasive objective tests in the battery used by pediatric audiologists to diagnose degree and type of hearing loss. They are accomplished by recording the electrical far-field response to stimulation of the auditory system using electrodes attached at designated positions on the child’s head while the child is asleep or inactive. Otoacoustic emissions are measured by placing a probe in the child’s ear canal to measure elicited or naturally occurring acoustic emissions from the cochlea. Immittance audiometry is use of a tool that infers middle ear function. All of these procedures provide indices of residual hearing and require no voluntary response or participation by the child.

2 Behavioral observation audiometry, visual response audiometry, and conditional play audiometry are techniques used by pediatric audiologists that involve observing a child’s response to sound, or conditioning or teaching a child to respond to sound, in a controlled manner. These types of measures require the child to be awake, alert, and (depending on the task) involved in the testing. They are voluntary, behavioral responses to sound that are used to determine degree and configuration of hearing loss.
not an event. For many infants with a conductive hearing loss overlying the sensorineural loss and/or progressive hearing loss, the definitive diagnosis may be a moving target. Other comorbid conditions may also deter acquiring a complete audiological profile. For example, the incidence of auditory neuropathy, which has been linked to neonatal concerns such as prematurity, hyperbilirubinemia, and respiratory distress resulting in the need for ventilation, will limit the audiologist’s ability to rely on electrophysiological measures to determine the degree of hearing loss. Hearing levels may fluctuate, and the child may not be developmentally able to provide reliable behavioral information to document the hearing loss. This is a prime example of the challenges an audiologist encounters in trying to produce an infant’s first audiogram. Expertise and patience, combined with support from parents and insight from early interventionists, contribute to the diagnostic process. Once hearing loss is defined, hearing levels should be monitored for stability, and appropriate amplification should be pursued. Deviation from the recognized ideal timeline to diagnose hearing loss and pursue amplification can result in less than optimal results. This is a significant source of variability in outcomes for children with cochlear implants.

Children who have progressive hearing loss may not be identified by newborn hearing screening. Astute parents and pediatricians who recognize the characteristic behaviors associated with hearing loss must follow up their concerns with a hearing screening, and then a full diagnostic assessment if indicated. The sooner hearing loss is identified, the sooner intervention in the form of amplification and therapy can begin. Late identification of hearing loss results in a greater need for remedial services to bridge the gap in communication development as the child ages (Yoshinaga-Itano, 2003; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998).

**USE OF ASSISTIVE TECHNOLOGY**

The recognized best practice for fitting amplification in infants with hearing loss is to collect the audiological data as soon as possible and then use prescriptive targets when setting hearing aids to achieve audibility within the child’s residual dynamic range (Pediatric Working Group, 1996; Seewald, Moodie, Sinclair, & Scollie, 1999; Westwood & Bamford, 1995). This should be done in a timely manner, with the goal of fitting amplification within a month of diagnosis. A significant source of variability in outcomes begins to take root at this stage of intervention. When actual practice deviates from this best-practice model, the deaf infant, already deprived of audition for the first few months of life, and possibly before birth, continues to develop without the necessary input to develop the auditory areas of the brain.

The longer a child functions with limited or no auditory information, the greater the delay in spoken language acquisition becomes. Deaf children who use visual communication, including American Sign Language, Signed English, or Cued Speech, may develop language constructs that enable communication, but they do not develop audition skills, which are the basis of spoken language. The goal of fitting amplification is to deliver sound that is meaningful to the developing
infant. The child’s degree of hearing loss dictates the effectiveness of amplification. Distortion and noise often accompany the signal from high-gain hearing aids. Deaf children may obtain sound awareness and the ability to detect their parents’ and their own voices, but sound may not be sufficiently clear to convey the acoustic features of connected speech in a manner that they can meaningfully process. If this is the case, then timely discovery of this situation is essential. On the contrary, if children have residual hearing and have been diagnosed early and well fit with amplification, and have had abundant and purposeful auditory stimulation in a controlled environment, they may develop the foundation skills upon which to build a spoken language system. This is the crucial decision point when determining a baby’s candidacy for cochlear implantation. Children with some auditory experience, even if it has not afforded spoken language acquisition, are likely to recognize the presence and potential meaning of sound. Children who have no previous experience with sound will have to acclimate to its presence and then learn to attend before they begin to associate it with meaningful information. Thus, the reasons to pursue conventional amplification prior to cochlear implantation are twofold: first, to determine whether conventional amplification will enable access to spoken language acquisition, and second, to stimulate remaining hearing, and thus the auditory brain, to the fullest extent possible. If the child is a candidate for cochlear implantation, even limited auditory experience via conventional amplification could expedite the continued development of auditory skills. On occasion, a hearing aid trial will be deferred, but this should be the case only when it has been established that the child’s residual hearing is insufficient for noninvasive measures to be of benefit.

Per United States Food and Drug Administration guidelines, cochlear implantation is limited to children who fail to make progress in auditory skills development using conventional hearing aid technology. The lower age boundary for a child to undergo cochlear implant surgery has changed over the years. In 1986, when multichannel cochlear implants were first used in a clinical trial to evaluate safety and efficacy, the lower age limit was 2 years. In 1998, this changed to 18 months, and by 2000 it was lowered to 12 months of age. The limiting factors in providing a cochlear implant at an even younger age include confidence that the child is indeed a candidate by audiological and surgical criteria. The theories propelling earlier implantation are based in developmental research (see Harrison, 2002, for review). They speak to the importance of providing meaningful auditory stimulation before critical periods of normal development are missed, causing delays in language development, which in turn leads to barriers in cognitive and social-emotional development. In the auditory system, areas of the cortex will reorganize following a period of sound deprivation (Kral, Hartmann, Heid, Tillein, & Klinke, 2001; Sharma, Gilley, Dorman, & Baldwin, 2007). If cortical reorganization is arrested, ensuing auditory development will follow a more normal course. Clinical research investigating the effect of age at implantation has supported the notion that earlier implantation impacts speech perception performance. Fryauf-Bertschy, Tyler, Kelsay, Gantz, and Woodworth (1997) found that speech perception outcomes for prelingually deaf children implanted
prior to age 5 were significantly better than outcomes for children implanted after age 5. Kirk et al. (2002) studied differences between prelingually deaf children implanted before and after 3 years of age and, again, found significant differences in group performance, with early implanted children demonstrating faster rates of growth in performance on speech perception tasks. Recent studies have explored the risks versus the benefits of implantation under 12 months of age. Dettman, Pinder, Briggs, Dowell, and Leigh (2007) demonstrated that in the hands of experienced pediatric cochlear implant centers, cochlear implantation may be performed safely in very young children. In this study, progress was measured using an infant language scale; language growth rates for children receiving implants before the age of 12 months were significantly greater than rates achieved by children receiving implants between 12 and 24 months, and they matched growth rates achieved by normally hearing peers.

In addition to age at implant, the audiological criteria for pediatric cochlear implantation have changed over the years as the benefits of this technology have become more widely recognized. The candidates for the first multichannel cochlear implants were children with essentially no measurable hearing; today, we provide cochlear implants to children who can be reliably tested and are able to recognize up to 30% of words presented in isolation. Studies of adults comparing residual hearing and postimplant performance suggest that some correlations exist, but outcomes are confounded by other factors, such as duration of deafness (Cullen et al., 2004; Friedland, Venick, & Niparko, 2003; Gomaa, Rubinstein, Lowder, Tyler, & Gantz, 2003). However, there is evidence that this comparison is more compelling and multifaceted in pediatric studies. Children with more residual hearing often make greater progress with cochlear implants and progress at a faster rate than children with little or no residual hearing (Cowan et al., 1997; Gantz et al., 2000, Zwolan et al., 1997). This may be due to development of the central auditory pathway, afforded by better peripheral stimulation and greater plasticity in early development.

Previous experience with sound is another source of variability among children who use cochlear implants. Children with sudden onset of hearing loss or a progressive loss with onset of deafness after language acquisition have historically demonstrated speech perception benefits more quickly than children who are congenitally deaf (Fryauf-Bertschy, Tyler, Kelsay, & Gantz, 1992; Miyamoto, Osberger, Robbins, Myres, & Kessler, 1993; Nicholas & Geers, 2006).

The benefits of an established language base and previous auditory experience provide the child with reference points when hearing with an electrical signal. That is, children learn to map the new signal to their memory of sound and spoken language.

The postimplant audiological care and management is of great importance when considering differences among deaf children with cochlear implants. This is a significant source of diversity in outcomes, and one that can be impacted if the parent and child are motivated and resourceful. This includes the consistency of device use, regularity in monitoring hearing and optimizing the programming of the speech processor, and consistent maintenance and upgrading of the hardware.
Predictors of Success for Children With Cochlear Implants (Geers, Brenner, & Davidson, 2003). Selective use or nonuse translates to a delay in the development of auditory skills. Use of well-maintained equipment and frequent checks of hearing levels and speech perception performance are critical to ensure that a child is realizing the full benefit of the technology. Children who receive cochlear implants at older ages often have more difficulty in maintaining the motivation to use a device that may not provide immediate benefit. Support from family and an educator is essential and is another source of the variability in a child’s acceptance of and benefit from a cochlear implant.

ANATOMICAL, MEDICAL, AND DEVELOPMENTAL FACTORS

The audiological aspects of a child’s development are only one facet of the whole child that will affect the outcome of therapeutic interventions. A critical medical consideration is the anatomical status of the cochlea and the integrity of the auditory nerve and the higher auditory pathways. In addition, the presence of cognitive delays and developmental conditions may impact a child’s ability to use the technology and benefit from therapy.

Advancements in the medical science of anatomical imaging have provided the cochlear implant surgeon with the tools needed to clearly visualize the cochlea and its nerve supply (Buchman et al., 2006; Gleeson et al., 2003; Kerr & Backous, 2005). The computed tomography scan and magnetic resonance imaging are clinical tools that are used to determine cochlear patency and the presence of the auditory nerve. More recent research has led to means of imaging the electrode array in vivo (Skinner et al., 2007), which illuminates the interface between the implant array and cochlear structures. It must be recognized that cochlear implant technology has limitations when applied to grossly abnormal anatomy. Some children with cochlear malformations have received implants and attained good detection and reasonable speech perception abilities, but for many, the devices serve mostly to supplement visual information (Buchman, Copeland, Brown, Carrasco, & Pillsbury, 2004). Expectations for outcome and the goals of therapy may need to be adjusted for a child if, despite aggressive programming of the device and consistent auditory intervention, there is insufficient stimulability resulting in reduced clarity of sound.

The cochlear implant delivers stimulation at the peripheral end-organ of hearing: the cochlea. We can engineer the way sound is detected and changed from an acoustic signal to electrical impulses and then amplified, filtered, and coded before it is delivered to the cochlea. However, the way the auditory nervous system analyzes the information and processes it in the higher regions of the auditory brain stem and cortex is beyond our control. Herein lies a major source of variability among children. Although an individual child’s brain may be able to recognize patterns of stimulation that are perceived as words or phrases, that child’s attention, cognition, and memory abilities affect the overall ability to process language (Fagan, Pisoni, Horn, & Dillon, 2007; Pisoni, 2000). These may be target areas for therapy that require a comprehensive approach.
It has been reported that 30–40% of children with significant hearing loss who may be candidates for cochlear implants also have other development issues (Karchmer & Allen, 1999; Parrish & Roush, 2004; Picard, 2004). These handicaps often affect a child’s prognosis for success, when success is defined as age-appropriate spoken language development. Many clinical reports have been published regarding children with blindness, mental retardation, autism, and other sensory and cognitive disorders who have received cochlear implants (Fryauf-Bertschy, Iler Kirk, & Weiss, 1993; Holt & Kirk, 2005; Waltzman, Scalchunes, & Cohen, 2000). In general, these studies support the position that children with multiple handicapping conditions can learn to use audition with varying levels of benefit and, typically, at slower rates of progress compared with their peers with no other diagnoses. For some of these children, cochlear implantation will support communication, and for others, its benefit can better be described as providing a connection to the environment. Especially in these cases, it is critical that family and educators work together to explore and capitalize on each child’s potential. The presence of other handicapping conditions certainly increases the need for counseling with the family in regard to appropriate expectations and the need for supplemental resources.

FAMILY GOALS AND THE DEFINITION OF SUCCESS

Cochlear implantation, being an elective procedure, is a choice parents make for a child for the purpose of gaining the sense of hearing. The functional use of hearing may vary depending on a child’s general development and parents’ goals for the child. Before discussion of the individual differences in families, environments, and therapies that affect outcomes in children who use cochlear implants, it is important to recognize that the conventional way to measure results in the area of communicative disorders is to compare performance with the developmental patterns and timelines of normal speech and language acquisition. However, normal speech and language acquisition is not necessarily commensurate with the definition of success for every child with a cochlear implant. Success is defined as a function of the goal for the individual; that goal may be very conservative, such as sound awareness for safety, or it may be ambitious, such as age-appropriate speech and language acquisition. For the purposes of this discussion, we acknowledge that the long-term goal for each child is to reach his or her potential in communicative competence. However, to quantify outcomes in cochlear implantation, we use measures of speech perception performance and normative indices of speech and language acquisition. Thus, the measurement tool of choice depends on the purpose of assessment.

THE FAMILY AND ITS ENVIRONMENT AND RESOURCES

In counseling parents about what it will take to help their child achieve the goal of effective communication, which is a cornerstone to building a life’s achievement academically, socially, and personally, we sometimes refer to the technology as the
“tools” and the parents and therapists as the “technicians.” Undoubtedly, the tools have improved and will continue to improve over time. Certainly, the hearing aid and cochlear implant technology that is available today is more sophisticated, flexible for individual fitting, durable, and user friendly than the first generations of these devices. Simply said, better tools or technology provides better results. However, to understand the variability of individual outcomes in cochlear implantation, we must also recognize that some technicians have more natural ability, practice, and expertise than others. In addition, some families have more barriers to overcome as they strive to become competent technicians. Much of the variability in therapeutic outcomes for children with cochlear implants correlates with the family’s ability to navigate medical and educational needs independently by overcoming potential language, economic, and/or social barriers. Other family variables that influence a child’s rate and level of progress with a cochlear implant include acceptance and vigilance, stability of the family’s structure, and access to and commitment to therapy.

The family’s acceptance of the diagnosis and the family’s ability to move forward will likely affect the timeliness and efficacy of intervention. A family with no history or experience with hearing loss may struggle to recognize the long-term impact and permanency of deafness. For example, the family members may perceive cochlear implantation as “the fix” for deafness, with little appreciation for the importance of ongoing therapy. Families must be counseled to understand that the continuous use of well-maintained technology, coupled with consistent and appropriate therapy, is the key to deriving maximum benefits from its use. This requires thorough counseling from clinicians who recognize when a family needs more instruction and support in using and maintaining hardware as well as encouragement to participate in therapy services.

Family structure and support are considerable sources of variability in cochlear implant outcomes. However, it is difficult to objectively measure these because of the number of confounding factors they include and our inability to conduct a causal study. It is typical for children to learn language from parents and other family members. Families whose members participate in regular therapy with their children and learn how to carry over the therapeutic principles and practices to everyday life contexts will provide the optimal environment for a language-developing child. It is important to look at individual differences in families’ organization to help determine how provision of therapy will best work for their particular situations and obligations. Some of these potential differences include single-parent families, families where both parents work full time, families that live in rural areas, and families with low socioeconomic status, who often have fewer economic and educational resources. Regularly scheduled intervention, ideally weekly therapy sessions, is essential to support parents as they nurture the language development of the child. Single parents may need help analyzing their schedule to determine when a weekly therapy session can take place. It will be important for them to establish support from family and/or friends in order to meet all of their responsibilities, including therapy with their child. The implant team can provide documentation to employers as needed to allow time off for the session. A letter explaining the importance of therapy and why it is critical for the
Individual Differences Affecting Therapeutic Change

Parent to be consistently involved can often convince an employer to allow a longer lunch hour or for the parent to leave work early once a week. Families with two working parents and a child who spends a great deal of time in daycare or with another primary caregiver may need other types of flexibility. The primary caregiver can attend therapy with the parent or the session can be recorded for parents to view later so that they too can carry over goals while they are with the child.

The economics of acquiring therapy services is a concern for many families. Most families can access resources through insurance, Medicaid, scholarships, and local community organizations or parent support groups. When families do not have access to resources, either because of logistics or the lack of financial means to acquire them, valuable time may be lost in intervention, which impacts overall outcomes (Yoshinaga-Itano, 2003; Moeller, 2000).

Families living in metropolitan areas may find a variety of sources to access appropriate services. Families that do not have appropriate services available in their local area may have to travel long distances for services. One strategy for overcoming this problem may be to find a local therapist who can work with an experienced therapist in a mentoring relationship. Current technology such as videotaping and webcams to provide distance health services can make this process more feasible. This not only allows for access to qualified professionals but also decreases costs for families for both therapy and transportation. Although Medicaid law does not currently recognize this as a distinct service, Medicaid reimbursement can be obtained in at least 18 states at this time (http://www.cms.hhs.gov/Telemedicine/08/31/08).

We cannot presuppose that socioeconomic factors that can be quantified, such as income and number of parents in the household, will always impact outcomes in a predictable way. The University of North Carolina-Chapel Hill’s Center for Acquisition of Spoken Language Through Listening Enrichment (CASTLE) provided weekly parent sessions to 20 children in December 2007. The families of these children represent many of the individual differences found in families throughout the country. Three of the families did not speak any English, four of the children were in single-parent homes, six mothers worked full-time jobs, and seven families’ annual gross income was less than $30,000. All but 4 of the children were demonstrating average to above average progress, as defined by making a year’s progress in a year’s time.

Educational and Therapeutic Methods

In addition to the variables previously discussed, successful therapeutic intervention hinges on the ability of intuitive and creative therapists to lead parents in the art of developing the auditory skills of the child. In recent years, there have been a multitude of books, guides, materials, and intervention programs developed to help parents and therapists teach children with cochlear implants to meet their communicative potential. From a therapeutic standpoint, to apply the same theories and practices without regard for the strengths and weaknesses of the individuals involved in the process can result in frustration, disappointment,
Predictors of Success for Children With Cochlear Implants

and ultimately, failure to achieve the personal potential of the child and family. The ideal scenario includes (a) access to experienced therapists, (b) parental involvement in therapy, (c) carryover of concepts from therapy to daily life, (d) importantly, an emphasis on the development of audition skills, and (e) the integration of and reliance on hearing as the main mode for communication.

**EXPERIENCED THERAPISTS**

Although aggressive audiological management is being pursued, parents also need to establish appropriate auditory-based therapy services with a therapist trained in the development of spoken language through audition. It is important for parents to work with their cochlear implant team to discuss the types of services that are available in their area and how to advocate for and establish services. Parents should determine the following (Estabrooks, 1998; Ernst, 2001): Does the therapist expect a child to learn through listening and teach the child how to obtain information through hearing? Do they understand how the environment can interfere with listening? Do they follow normal patterns of language and speech development? Does the therapist work with the parents as partners in developing their child’s goals as prescribed in family-centered practice? That is, parents must be encouraged to assess the quality of therapy they are receiving. See Table 12.2 for a delineation of features of adequate therapy.

**PARENTAL INVOLVEMENT**

It is important for one or both parents or another caregiver who is very knowledgeable about the child to participate in these sessions on a weekly basis. The goal of the therapist in this session is not to directly teach the child but to teach the parent how to, first, stimulate the child to develop the child’s auditory and language potential, and then to implement the carryover of goals at home on a daily basis. Parents and caregivers need to be their children’s primary language teachers. Therapists can make the greatest impact on a child’s development by teaching the parent the skills for developing audition skills and language. Effective therapists must incorporate elements of adult learning into the time spent with the parent and child so that parents develop confidence, competence, a level of energy, and motivation. Parents then incorporate therapy goals into normal caregiver routines, facilitating children’s learning of language in their home environment.

**CARRYOVER AT HOME**

Once appropriate services are established, parents will need to carry over goals established in therapy at home. Many of the scheduling issues previously discussed can impact parents’ consistency in doing this. However, without carryover, the child’s progress will be very slow based on the limited amount of time spent with the therapist. The therapist can help parents prioritize their day and determine where daily carryover activities best fit.
Individual Differences Affecting Therapeutic Change

TABLE 12.2
Families can consult the document “Ten Principles of Auditory-Verbal Therapy” as a first step when learning about the components of appropriate therapy.

1 Promote early diagnosis of hearing loss in newborns, infants, toddlers, and young children followed by immediate audiologic management and Auditory-Verbal therapy and use of appropriate, state-of-the-art hearing technology to obtain maximum benefits of auditory stimulation.

2 Guide and coach parents to help their child use hearing as the primary sensory modality in developing spoken language without the use of sign language or emphasis on lip-reading.

3 Guide and coach parents to become the primary facilitators of their child’s listening and spoken language development through active consistent participation in individualized Auditory-Verbal therapy.

4 Guide and coach parents to create environments that support listening for the acquisition of spoken language throughout the child’s daily activities.

5 Guide and coach parents to help their child integrate listening and spoken language into all aspects of the child’s life.

6 Guide and coach parents to use natural developmental patterns of audition, speech, language, and cognition and communication.

7 Guide and coach parents to help their child self-monitor spoken language through listening.

8 Administer ongoing formal and informal diagnostic assessments to develop individualized Auditory-Verbal treatment plans.

9 Monitor progress and evaluate the effectiveness of the plans for the child and family.

10 Promote education in regular schools with peers who have typical hearing and with appropriate services from early childhood onwards.


Daily activities focusing on carryover need to take place in a quiet environment. Many normal-hearing adults are not aware of the various environmental noises that can negatively impact a child’s successful listening, such as the dishwasher, ringing phones, and television. These sources of noise need to be minimized or eliminated during time set aside for home carryover activities. Other elements that may enhance the listening environment include parents and/or therapists sitting beside the child’s chair on the side of the best ear, speaking to the child close to their cochlear implant microphone, at a normal speaking volume, and using a technique referred to as acoustic highlighting (Estabrooks, 1998). One example of acoustic highlighting is to use a sing-song voice, also referred to as parentese, to make the phrase more audible and interesting to the child.

CONSISTENT AUDITORY AND SPOKEN LANGUAGE INPUT

Language and listening should be incorporated into the child’s daily routine throughout the day. Isolated drills in “auditory training” once per day for an hour...
will be insufficient for a child to learn to integrate sound for meaningful, age-appropriate communication. Instead, a child must be immersed in an environment of “auditory learning,” where all routines are seen as opportunities for the child to listen and be exposed to language. The child needs to know that he or she is expected to listen. Normal caregiver routines such as feeding and dressing a child are rich in language that is repetitive and includes the vocabulary first learned by children with normal hearing. These care-giving routines should be done within close proximity to the child, which is important for providing an optimal auditory environment. Incorporating phrases from routines that the child participates in every day can help children pick up auditory and language skills in a developmentally appropriate way. Including songs in daily activities that embed age-appropriate language features will gain the child’s interest and attention.

**COMMUNICATION MODE**

Communication mode is the predominant feature of various theories and methods for educating children with hearing loss that are often described on a continuum ranging from no codependence on auditory information for communication to total and complete integration of audition for communication. Children with cochlear implants use a variety of communication approaches including American Sign Language, Total Communication, Cued Speech, Auditory–Oral, and Auditory-Verbal, as well as forms of augmentative alternative communication. Although the literature does not support a single communication mode as being clearly superior for children with hearing loss as a group because of their heterogeneity (Moeller, 2000; Yoshinaga-Itano, 2003), the preponderance of studies of children with cochlear implants show higher levels of speech perception performance and spoken language acquisition among children utilizing oral communication modes over those using visual or combined communication modes. Research has shown that children educated in a spoken language approach without the use of sign demonstrate more sophisticated narrative skills, greater vocabulary size, greater use of more bound morphemes, and use of longer utterances with more complex syntax in their spontaneous language than children taught a signed communication system (Geers, Nicolas, & Sedey, 2003). In addition children from oral programs have also been shown to demonstrate higher speech perception scores and more age-appropriate speech production, oral language, and total language (Kirk et al., 2002; Moog & Geers, 2003; Osberger, Fisher, Zimmerman-Phillips, Geier, & Barker, 1998). Improved spoken language skills have been shown to result in increases in reading skills. Although a recent study by Geers (2003) demonstrated that speech perception scores did not contribute as an independent variable to reading outcome in children with hearing impairments, speech production and language skills were shown to predict their reading success.

Reasons for selecting a particular communication mode should be the prerogative of well-informed parents who recognize their child’s potential and limitations. Most parents seeking cochlear implantation for their child have normal hearing themselves; they often express the desire for their deaf child to acquire intelligible
speech and achieve speech understanding that will enable the child to participate in a mainstream educational setting. Parents need to be counseled regarding expectations for their child; other medical or developmental characteristics of the child may make mainstream education unrealistic. It may be necessary for a child to rely on a combination of visual and spoken communication. Parents are the most powerful force influencing a child’s success with any communication approach. As stated by Luterman (1999), “No educational method is going to work unless parents freely choose it and take responsibility for it.” Thus, although choice of communication mode is very important, the family’s commitment to following through with supporting the remedial practices for becoming competent teachers of language through that chosen option is even more important. An environment that provides consistent and appropriate language models, whether signed, cued or spoken, is the most desirable. The parents’ or primary caregiver’s role is pivotal in affecting competent use of that communication mode.

CASE STUDIES

As noted, a child’s success with a cochlear implant is impacted by many variables. The following case studies represent a range of patient characteristics, expectations, and outcomes among children who have received cochlear implants.

SARAH

Sarah was diagnosed with a severe to profound hearing loss at 6 weeks of age after being referred by an infant newborn hearing screening at her birth hospital. There was no history of hearing loss in her family and no risk factors associated with her mother’s pregnancy or the birth. Genetic testing later revealed her cause of deafness was related to a Connexin 26 mutation. She had normal cochlear anatomy and was a healthy baby. She was the second child born to a two-parent home. Both of her parents were college educated, and the family was socially and financially stable. Sarah was fit with hearing aids at 2.5 months of age and began receiving early intervention services with a certified auditory verbal therapist shortly thereafter. Sarah’s developmental milestones unrelated to speech and language were typical. Despite consistent hearing aid use and some evidence of sound awareness, Sarah did not make the expected progress in acquiring auditory skills. She received an implant at 12 months of age. The expectations of the cochlear implant team and Sarah’s parents were that she would develop age-appropriate spoken language skills and be able to successfully enter a mainstream kindergarten classroom with her peers.

Sarah and her mother attended weekly auditory-verbal therapy consistently, and her family carried over her goals on a daily basis at home. Her audiological management was consistent and aggressive. She began to make progress right away, producing more frequent and varied vocalizations and alerting to voices and sounds in the environment. At the age of 2, she received a second cochlear implant. Her annual speech, language, and hearing assessment at the age of
3 years, 2 years after receiving her first cochlear implant, revealed detection of sound at 20–25 dB HL across audiometric frequencies, excellent speech recognition abilities, and speech production and receptive and expressive language scores within normal limits or above. She continues to demonstrate communication skills comparable to those of normal hearing children of her age.

**Rob**

Rob is a child with multiple disabilities, including profound hearing loss. After a normal pregnancy, birth, and early childhood development, Rob contracted meningitis at 9 months of age, which resulted in a total loss of hearing as well as concomitant cognitive and motor delays. He was fitted with conventional hearing aids by his first birthday, but he obtained little more than sound awareness. His general development stagnated for months after the meningitis, but he slowly began to recover motor function. However, his cognitive abilities were severely and negatively affected by the insult of meningitis.

Rob is the second child born to college-educated parents who are highly motivated for him to succeed. They are very aware of and have accepted his other disabilities. Rob received a cochlear implant at the age of 4 years. The expectations of the cochlear implant team were for Rob to develop some sound awareness skills to augment communication. Although his responses to sound were slow to emerge after implantation, he eventually became very attached to his cochlear implant, requested it, and wore it consistently. Rob responds alertly to his name and many environmental sounds that are routine in his environment.

Rob attends a special education class in his local school system. He also receives weekly therapy from the cochlear implant center to address his audition goals. Because of the dedication of his mother, he has not only met expectations for sound awareness but has also begun to understand some functional spoken phrases and words. Rob has demonstrated limited use of his voice. He will vocalize for attention or with emotion, but does not vocalize for expressive communication. His receptive language, however, appears to be emerging. His parents have begun to pair signs with speech and very recently, he has begun to use sign expressively in specific situations and in response to information being presented to him through listening. Expectations for his continued growth in communication are unknown but unlimited by his parents’ support and this educational and therapeutic environment.

**Jennifer**

Jennifer received a cochlear implant at the age of 13. Even though she was diagnosed as profoundly deaf shortly after birth, she did not use assistive technology, as her severe bilateral cochlear malformations led surgeons to believe that neither hearing aids nor cochlear implants would enable auditory stimulation. Her parents approached communication aggressively and began using Cued Speech with her at a very young age. With no residual hearing but with consistent intervention
services, Jennifer was able to maintain academic achievement commensurate with her hearing peers through use of Cued Speech and her parents’ ongoing support. In a final attempt to obtain sound awareness, her parents elected to pursue an auditory brainstem implant (ABI) in Europe. Although it is not approved for use in nontumor patients in the United States, the ABI has been used with a small number of children in Europe, with reportedly good results for sound awareness. In gathering medical records for the ABI consultation, new imaging was collected that, due to improved resolution, suggested to an experienced surgeon that Jennifer may in fact have a patent internal auditory canal with an intact eighth nerve on one side. She underwent cochlear implantation with guarded expectations that she would hear. The result was a partial insertion of the electrode array with effective stimulation on about one third of the available channels. Although the development of auditory skills has been reliant on intensive therapy and painstaking drill, Jennifer uses her cochlear implant during all waking hours and increasingly relies on sound. She alerts to her name, recognizes the voices of her family, and understands words and phrases in closed-set tasks. Her lip reading has also improved, and her reliance on Cued Speech has declined, which affords her many more communication partners. Jennifer’s intelligibility is also improving, as she is finally able to monitor her voice. She is highly motivated and determined to make continued progress.

For these children, expectations for benefit from a cochlear implant were varied. They have all been successful based on their individual differences and goals. Although they differ in many ways, all three case studies include the important variable of supportive parents who are involved in the therapeutic process.

WHERE DO WE GO FROM HERE?

As a nation, our success in identifying hearing loss at birth and following up with timely fitting of assistive technology is improving. In 1985, when multichannel cochlear implants were first used under investigational trials, hearing screening procedures were insensitive and nonspecific, identifying only a fraction of children in the population with hearing loss. There was no consensus regarding the best way to identify and habilitate children with hearing loss before important milestones in their development had passed. At the time of this writing, our success rate has greatly improved. A survey of state-mandated hearing screening programs by Harrison, Roush, and Wallace (2003) indicated a positive trend toward earlier identification of hearing loss and hearing aid fitting as a direct result of newborn hearing screening. Efforts are now focusing on subsequent intervention and the availability of well-trained professionals to implement early intervention and preschool and elementary school services. Although more parents are choosing cochlear implant technology and spoken language for their children who are deaf, university training programs are not responding quickly to this need. A recent survey indicated that out of the 70 universities in the United States that have deaf education programs, only 8 have a specialization in auditory-based education. Training programs for teachers of the deaf and speech-language pathologists
need to prepare future professionals to become competent in teaching children to develop spoken language skills through listening (White, 2006).

Continued development of effective therapeutic methods to use with all children with severe to profound hearing loss is critical. We should target special populations of children who require a flexible and thoughtful approach, such as those with multiple handicapping conditions, children from families who are not native speakers of English, and children from families who are socially and economically disadvantaged and may require assistance with general living and parenting skills. The diversity among children with hearing loss and their families is unlimited. Our ability to recognize and appreciate differences among children is the first step in helping them achieve their individual potential after cochlear implantation.

Diversity is the one true thing we all have in common. Celebrate it every day.

Anonymous

REFERENCES


Individual Differences Affecting Therapeutic Change


Predictors of Success for Children With Cochlear Implants


Author Queries

AQ1: Please indicate whether Table 12.1 is reproduced directly from the source (permission needed), after/modified/adapted (no permission needed), or used courtesy of (no details or permission needed, but use the phrasing “courtesy of”). Also, in Table 12.1, please define EDHI.

AQ2: Please check relative heading weights throughout.

AQ3: Spelling of Zwolen has been changed to Zwolan to match the reference list. Please confirm or adjust if needed.

AQ4: OK to replace “craftsmen” with “technicians”?

AQ5: Unable to reach the Web page cited in the sentence beginning “Although Medicaid law.” Please check URL and update to current page.

AQ6: In the sentence “Do they follow normal patterns of language and speech development?” please confirm that “they” refers to the parents or clarify phrasing.

AQ7: Table 12.2 seems to be reproduced directly from another source. Please confirm exact quotation and confirm that permission to reprint this material has been obtained.

AQ8: Please provide table title for Table 12.2.

AQ9: Please supply page number for Luterman quotation.

AQ10: Please write out HL.

AQ11: Please supply date of retrieval for A.G. Bell Academy 2007 (reference list and Table 12.2).

AQ12: For Fryauf-Bertschy et al. 1993, please supply volume number.

AQ13: Gillespie, M. (1990) does not appear in the text. Please adjust, add to text, or delete from list, as appropriate.

AQ14: For Harrison 2002, please supply city of publication and publisher.

AQ15: Two references are given in the list as White, 2006. Only one citation appears in the text. Please check throughout and adjust as needed (add to text or delete from list). If two White 2006 references are needed, please distinguish them as 2006a and 2006b.