Language Development in a Hearing and a Deaf Twin With Simultaneous Bilateral Cochlear Implants

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Received October 24, 2009; revisions received April 1, 2010; accepted April 7, 2010

This case study is an examination of the language development of a single pair of fraternal twins—one with a profound, sensorineural hearing loss who received simultaneous bilateral cochlear implants at 1 year of age and the other with normal hearing. The purpose of the study was to compare the twins’ language development over time from 6 months to almost 3 years of age. Findings suggest that early simultaneous bilateral implantation supports the development of age-appropriate language, thus increasing the potential for overall progress commensurate with hearing age peers.

It is typically the case that deaf children exhibit delayed language development relative to their hearing age peers. Studying the language development of a set of fraternal twins—one born with a profound, sensorineural hearing loss who received simultaneous bilateral cochlear implants at 1 year of age and the other with normal hearing provides a singular opportunity to examine this issue in a very unique context. Given simultaneous bilateral implantation at this early age, it would be anticipated that the deaf twin’s progress would approximate that of her hearing sister. The goal of this study was to determine the extent to which this was the case by comparing the twins’ language development over a 28-month period from 6 months to 2 years, 10 months of age. Findings from this study have potential to contribute to the literature on language development in deaf children with simultaneous bilateral cochlear implants, a line of inquiry that is still in its early stages. To this end, the primary focus was on the following research question: to what extent was the deaf twin on track with her language development relative to hearing age norms, and how did she compare with her hearing sibling?

Language Development in Children With Cochlear Implants

The outcome of language development following cochlear implantation has been reported to be variable across children (Dowell, 2005; Fryauf-Bertschy, Tyler, Kelsay, Grantz, & Woodwash, 1997; Tomblin, Barker, Spencer, Zhang, & Gantz, 2005). This variability in performance across children has been attributed to several factors including age at onset of deafness, length of auditory deprivation, and age at which a child received the cochlear implant. Even for children who receive an implant between the ages of 1 and 3, it could be argued that they are beginning to hear and talk after their motor, neurological, cognitive, and linguistic systems have already undergone substantial development (Ertmer & Mellon, 2001). Other factors that are more difficult to quantify, but may have equal or greater influence, are the nature of a child’s educational and home environment, the mode of communication used, and the amount and kind of rehabilitation training the child receives (Geers, 2006; Geers & Brenner, 2003). Understanding that the cochlear implant is an auditory device and that communication benefits will depend on additional factors is crucial to the informed consent process for candidates and their families (Berg, Ip, Hurst, & Herb, 2007).

That said, there are many positive documented benefits of the cochlear implant, most notably improvements in communication and rates of spoken language development (Dowell, 2005; Ertmer, Strong, &
Sadagopan, 2003; Papsin & Gordon, 2007; Tomblin et al., 2005; Waltzman & Roland, 2005). As a consequence, cochlear implantation generally appeals to hearing parents of deaf children and has become the preferred intervention following identification of permanent severe to profound hearing loss (Marschark, Lang, & Albertini, 2002). The choice of a cochlear implant is most often associated with the decision to use spoken language as the primary communication mode (especially for the deaf child in a hearing family) as it is seen as providing the best opportunity for the development of spoken rather than signed communication (e.g., American Sign Language) (Geers, 2006).

Recent studies suggest that the earlier children are implanted, the better the outcomes. It is reported that receiving an implant at a younger age may lead to more rapid improvements in speech perception and speech production than implantation later in childhood (Dowell, 2005; Ertmer & Mellon, 2001; Lesinski et al., 2006). For children with normal hearing, spoken language develops naturally given a typical language learning environment (i.e., exposure to accessible input in quantity and quality used in meaningful interactions with other capable users of the language) (Mayer, 2007). The primary goal of pediatric cochlear implantation is to provide critical speech information to the child’s auditory system as early as possible to maximize the chances of developing spoken language. What remains unknown is how much and how soon hearing must be made accessible to the developing brain of a child with a hearing loss to achieve auditory and speech development comparable to that of a hearing child.

There appear to be conflicting results regarding the effects of age at implantation on speech perception scores. Although a few studies indicate no advantage for children implanted at age 2 or younger, most studies report a clear advantage for very early implantation, especially during the first 2 years of device use. Svirsky, Teoh, and Neuberger (2004) report results for three groups of children who received an implant prior to 4 years of age. Using a statistical approach that compared the average size of the difference between growth curves over time, significantly higher speech perception scores were documented for children implanted before 2 years of age than for children who were implanted after age 2. Similarly, Baumgartner et al. (2002) reported that children who received an implant when younger than 36 months scored significantly higher in speech perception testing at 12, 18, and 24 months after surgery than did those who received the implant after the age of 36 months. Houston, Ying, Pisoni, and Kirk (2003) examined pre-word learning behaviors in a group of infants who had all been implanted by 25 months of age with the newest technology available. The study demonstrated that children who received cochlear implants between 7 and 15 months of age demonstrated the ability to learn associations between auditory and visual stimuli in a manner similar to hearing infants, whereas children implanted between 16 and 25 months did not.

With a reduction in age at implantation, research has shown that an increased proportion of children are achieving spoken language levels that are comparable to those of their hearing peers (Nicholas & Geers, 2006). Instead of linking age at implantation with only improved outcomes, early use of an implant is being linked to the real possibility of achieving normal, or close to normal, levels of speech and spoken language growth. In fact, current evidence indicates that children who receive implants before 2 years of age demonstrate rates of growth close to their hearing age peers. Differences that are noted in language performance between children with implants and their hearing peers are usually due to the existing delays in performance at the time of implantation for the later implanted population (Nicholas & Geers, 2006).

Because speech and language outcomes following cochlear implantation are influenced by a number of factors, it can be difficult to determine the independent contribution of age at implantation. However, a consensus seems to be building that 2 years of age represents a turning point in language development. Children who receive an implant at 2 years or younger appear to have an increased likelihood of normal spoken language development (Marschark, 2007). Papsin and Gordon (2007) argue that “the successful development of language in children with early-onset deafness is strongly correlated with cochlear implantation between 12 and 24 months of age. Implantation in infants with early-onset or congenital deafness, or both, before 12 months of age has been performed.
with good results” (p. 6). With early cochlear implantation and educational intervention, many young deaf children are ready for mainstream school placement, exhibiting age-appropriate speech and language skills, by 5 or 6 years of age (Nicholas & Geers, 2006).

Bilateral Cochlear Implantation

One often overlooked aspect of normal hearing not experienced by the typical implant recipient is the “stereo” effect of binaural hearing. In a normally hearing person, both ears receive auditory input simultaneously and the human brain is organized to receive and process sound from binaural sources. As cochlear implantation has developed from the early days of unilateral implants, increasing numbers of children are now receiving implants in both ears. The Ear Foundation has reported 130,000 implant users in the world, including 4,000 bilateral users as of 2007 (The Ear Foundation, 2007).

Balkany, Boggess, and Dinner (1988) reported the earliest descriptions of bilateral implants in the late 1980s. The primary reason for bilateral implantation in the early days was either that there was need for a technology upgrade (where one ear had a functioning but older single-channel device so the contralateral ear was fitted with a newer, multichannel device) or the device in one ear produced inadequate performance. As reported by Muller, Schon, and Helms (2002) in the late 1990s, bilateral implants were done solely with the hope and intention of providing binaural benefits. There has also been a trend toward simultaneous implantation of both ears rather than sequential implantation (i.e., one at a time, with a varying period of time between surgeries).

Bilateral implantation can improve the quality of hearing in many everyday listening situations and can provide significant advantages over unilateral implantation (Brown & Balkany, 2007; Ching, van Wanroy, & Dillon, 2007; Johnston et al., 2009; Murphy & O’Donoghue, 2007). In young children, there may be other compelling reasons for considering bilateral implantation. First, a young child’s auditory system is more plastic than that of an adult. Providing sound input to both ears in a young deaf child assures that sound is processed in both sides of the brain, maintaining plasticity and allowing the right and left auditory cortices to develop in a more normal sequence (Advanced Bionics Corporation).

Of primary interest has been determining whether or not bilateral implantation will produce improvements in understanding speech, particularly in background noise, relative to unilateral implantation. For most cochlear implant users, speech understanding in noise is relatively poor and they require higher signal-to-noise ratios than a normally hearing person. Word understanding for normal listeners in noise with both ears has been found to be as much as 40% better than listening with only one ear (Sammeth, 2007).

Bilateral cochlear implantation is still at a relatively early stage of research, and advantages and disadvantages of this form of binaural amplification continue to be investigated. Gordon, Valero, and Papsin (2007) performed a study measuring electrically evoked auditory brainstem responses to assess effects of bilateral electrical stimulation in children. This type of measurement assesses how quickly auditory information travels from the ear level to the brainstem level. A latency difference was detected in children with sequential bilateral implants, which indicated that auditory information appeared to be processed less efficiently and less quickly in the later implanted ear compared to the earlier implanted ear. Gordon, Valero, van Hoesel, and Papsin (2008) report that these differences in transmission time decrease with bilateral implant use of 3–9 months, but significant differences persist during this period in children with longer delays between implants. These findings indicate that the simultaneous implant group responses are the same in each ear at Day 1 and at a 9-month post-switch-on, suggesting that auditory pathways develop at the same rate and with the same efficiency when both ears are implanted at the same time, rather than sequentially.

Overall benefits to a binaural implant are sound localization, increased awareness of environmental sound, improved voice quality, access to a second device when one fails, and, most importantly, avoidance of auditory deprivation in the nonimplanted ear. It is also hypothesized that a bilateral implant will reduce duration of postimplant therapy by increasing the ease of listening and improving speech understanding in noise. Possible disadvantages are increased costs for
initial implantation and ongoing maintenance and more time and skill adjusting to the implants (for a discussion, see Ching, 2005).

Nature of the Study

This case study focuses on the language development of fraternal twin girls—one who was born with normal hearing (TNH) and the other who was born deaf (TD) and received simultaneous bilateral cochlear implants at 1 year of age. Their language was tracked over a 28-month period (from 6 months to 2 years 10 months of age) with the emphasis on gauging TD’s development relative to her hearing sister. There were four sources of data collected for the study: a structured interview, field notes and observations, formal assessments, and language samples. Written informed consent was obtained from the parents prior to the start of the study.

Structured Interview

The background information summarized in the following paragraphs was collected via a face-to-face interview with the twin’s mother and from field notes and observations. This interview was conducted in the family home at the beginning of the study. The interview followed a format structured to obtain background details relevant to the study. Some of the topics addressed included: birth details, developmental milestones, home environment, use of amplification, and communication strategies. The interview was audio recorded for later transcription and analysis.

Participants

The twins were born without complications following a normal pregnancy at 37.5 weeks gestation, just a half-week shy of full term for twins (38 weeks) and therefore not considered premature. TNH is older than TD by 2 min. Both girls were in the normal range for weight with TNH weighing 7 lbs 14 oz and TD weighing 6 lbs 15 oz. The girls were screened through the Ontario Infant Hearing Programme in the hospital within 1 day of their birth.

TNH passed the screening, whereas TD failed the initial hearing screening as well as the two follow-up screenings, at 6 and 8 weeks. The audiologist suggested visiting the pediatrician to determine if TD had a build-up of fluid, but an examination revealed no evidence of fluid in her ears. A fourth hearing screening was administered and TD failed it as well. At 4 months, a profound hearing loss was identified via Auditory Brainstem Response audiometry, and at 4.5 months, TD was formally diagnosed with a bilateral profound sensorineural hearing loss. Through follow-up blood testing, it was discovered that both parents carry a genetic trait for hearing loss.

TD underwent a Computerized Axial Tomography scan to determine any abnormalities or malformations of the ear structure and none were detected. She received trial hearing aids in July 2005 and wore them for 2–4 hr per day. It was a struggle to keep the hearing aids on and the parents reported no apparent differences in TD’s communication or listening skills after she began using them. The family communicated with her primarily through touch and gestures.

After diagnosis, the parents were presented with the range of communication options offered through the local Infant Hearing Program—American Sign Language, Dual or Auditory-Verbal. They were also informed that TD was an excellent candidate for simultaneous bilateral cochlear implantation given her age, family background, and the absence of any anatomical abnormalities. After researching the pros and cons of this option, the parents determined that this was the best choice for their daughter.

Three days before TD’s first birthday, she underwent cochlear implant surgery at the Hospital for Sick Children in Toronto. About 3 weeks later, she was fitted with her external processors (bilateral Freedom body worn processors), and the implant was activated approximately a week later when she was 12.5 months of age. Mapping of the implant followed and was accomplished over 3 days.

For the first month after activation, TD was quiet. It was evident, however, that she was listening as she would turn to sounds and point to what she was hearing (e.g., the plane overhead, water running in the sink). When asked about their decision to choose a bilateral implant rather than a unilateral implant, the parents were extremely positive. They reported positively on her development, noting that she could detect sounds readily, cope well in noisy environments, and localize without an issue.
TD attended weekly 1-h auditory-verbal therapy sessions in addition to weekly home visits by a teacher of the deaf and hard of hearing. The teacher and therapist worked with TD and her family to carry out ongoing assessments and establish language and listening goals. The home language was English and the home environment provided many rich language models and opportunities for language acquisition (e.g., conversations during shared meals, family discussions, books read throughout the day).

Field Notes and Observations

Field notes were taken over the course of 23 months, beginning when the twins were 7 months old and ending at 2 years 4 months. For the initial 9 months, notes were taken for 2 hr weekly, and for the second 10 months, they were taken for 2 hr every second week. During the last 4 months, notes were taken during three visits of 2 hr each. These notes included observations of the twins interacting with each other and with their environment. During each visit, age-appropriate materials and activities were utilized to stimulate natural conversation. Materials included storybooks, puzzles, blocks, and toys.

Formal Assessments

The SKI-HI Language Development Scale (LDS) (Watkins, 2004) and the Preschool Language Scale-4 (PLS-4) (Zimmerman, Steiner, & Pond, 2002) were each administered over the course of a 24-month period to obtain pre-, mid-, and postmeasurements for analysis of progress over time. The LDS was administered approximately every 4 months beginning at the age of 11 months for both twins, yielding a total of five assessments. The PLS-4 was administered only to TD approximately every 6 months after implant activation yielding two assessment scores.

The LDS is a parent report designed to track the receptive and expressive language levels of children with a hearing loss from birth to age 5. The scale is based on norms for hearing children according to age groups. In an early study of its reliability and validity (in which internal consistency, interrater agreement, and test-retest rater agreement were estimated), Tonelson (1978) reported that the LDS was a valid instrument for measuring language development in the population with hearing loss. For the purposes of the study, the parents reported language levels for both twins.

The PLS-4 is a standardized test of auditory comprehension (AC) and expressive communication (EC) for infants and toddlers. The AC subscale assesses basic vocabulary, concepts, and grammatical markers in preschool and higher level abilities such as complex sentences, making comparisons, and inferences in older children. The EC subscale requires preschoolers to name objects, use concepts that describe objects, express quantity, and use grammatical markers. For older children, it includes word segmentation, completing analogies, and telling a short story in sequence. This test also includes an articulation screener, a language sample checklist, and assesses behaviors considered to be language precursors.

Language Samples

Informal spontaneous language samples were collected during interactions between the twins and their family members (mother, father, older sister, and grandmother) and the researcher. The primary location for these interactions was the dining room in the family home. These samples were collected over the course of 19 months—weekly for a 9-month period and then biweekly for the next 10-month period. Notes were made during these interactions with respect to language patterns, echoing, imitating, and repeated and spontaneous utterances. Utterances were evaluated in terms of intonation, inflection, vowel, and consonant production. Substitutions or deletion of consonants were also noted (e.g., pookie for cookie).

Formal language samples were obtained during two sessions of 80 min each, working with each twin individually for 20 min and with the twins together for the remaining 40 min. Sessions were recorded using a Samsung digital camera on a tripod. The tripod was distanced approximately 1–1.5 m from the participants and positioned to obtain the most optimal face-on view of each participant for the duration of each language session. Age-appropriate materials and activities were used to encourage natural communication, interaction, and language for all sessions (e.g., storybooks,
a “create a face with stickers” interactive book, decorating a holiday foam shape). The twins completed the same sets of activities in the same order. The digital recordings were downloaded onto computer and then burned onto disc. Segments of these interactions were transcribed for future analysis—120 utterances for TNH and 93 for TD.

These spoken language samples were categorized using a framework based on the Tait video analysis component of the Nottingham Early Assessment Program (Archbold et al., 2004). The Nottingham Early Assessment Program provides a framework for evaluating young deaf children before and after implantation. The assessment is designed to gain a picture of the child’s functioning in everyday life, complementing the measures taken in the implant or audiology clinic. It was developed to look at the child and the family in nonclinical settings and to consider the areas of communication and language skills, auditory skills, and early speech production.

The Tait video analysis focuses on the child’s developing use of vocalization and auditory awareness of spoken language and “measures the child’s preverbal communication skills in interaction with a known adult including eye contact, turn-taking, vocal and gestural autonomy and auditory awareness” (The Ear Foundation, 2007). The Tait analysis provides standard conventions for coding utterances and allows the researcher to designate additional codes for representing correct and incorrect uses of language. Conventions utilized for the purpose of the current study included marking omissions, false starts, repetitions, abandoned utterances, no response, and gestures. As one video can provide information for more than one measure, in collaboration with a certified speech and language pathologist, further communication and language analysis was possible. The language conventions obtained in the video analysis were responding to questions, receptive language, expressive language, syntax, reading readiness, and unknown expressive vocabulary.

Results and Findings

In this section, findings are reported from the four data sources: the structured interview, field notes and observations, formal assessments, and language samples. Structured Interview

The twin’s mother reported differences in their early development. TD was a busy baby, actively exploring her environment. She was extremely visual, noticing the television and bright colors. Her mother describes her as a “self-entertainer,” easygoing, very independent, and not wanting to be confined in a playpen, car seat, or high chair. Although there were no behavioral concerns, TD could be called a high-needs child as she was demanding, had tantrums, and was emotionally impulsive. However, she was also easily redirected when involved in mischief. Her gross motor skills were well developed and she was sitting up at 5 months and crawling at 6 months.

In contrast, TNH was not as physically active and she was not as independent. She learned to sit up at 7 months and did not mind being confined in a car seat or a high chair. At 6 months, when TD was crawling, TNH was still lying on her belly trying to move around. TNH began crawling at the age of 10 months, whereas TD was already standing and moving along the furniture. However, at 11 months, there was a shift and TNH was taking three steps at a time, whereas TD had not yet begun walking. By the time she was a year old, TD was walking on her knees. Although she had taken one to five steps alone, she would look for an adult to hold her hands for security.

TD was reluctant to try new things (e.g., did not like meat), had difficulty with transitions, and could be stubborn. Although TNH exhibited some of these behaviors, overall she was much more compliant than TD. For example, if the girls were arguing over wearing a particular shirt, TD would win out and dictate what she wanted to wear. They tended to like the same things and did a lot of things together. They both enjoyed spending time with their older sister, who was 3 years old when they were born. TD followed her older sister around and liked to watch the same videos and do the same puzzles. TD would indicate which video she wanted to watch from her sister’s collection.

In the early going, TD would use various cries to communicate her wants and needs. For example, if she got stuck, she would cry until helped and then smile. She would use eye gaze to indicate where she was
going. TNH was more vocal and louder when she wanted something, making a lot of sounds and babbling to herself and others. She began to express sensitivity toward sounds (e.g., loud music).

Preimplant, neither twin had any formal language but they were able to communicate with each other. They laughed and giggled together during play. TD had a good attention span, could mimic actions and gestures, and was extremely visual and happy. Having a twin sister seemed to ameliorate many of the frustrations often displayed by profoundly deaf children as TD would rely on TNH for cues to help follow routines and meet expectations.

The relationship between the sisters did not change postimplant. They continued to share, explore, communicate, play, and interact with one another, but as they developed, they did display individual learning styles. TD is much more hands on, visual, and particular. If there was a piece missing from a puzzle, she would obsess over the missing piece until it was found. She also required more instruction to handle transitions. TNH did not display any of these behaviors.

The most significant difference between the girls was in the development of spoken language. Both girls enjoyed expressing themselves with language but in different ways. TNH’s language development was advanced for her age with clear speech, a large vocabulary, and grammatically correct utterances. However, overall TNH vocalized less than TD who was keen on telling her audience about everything she knew—even though her utterances were generally not intelligible.

Following the implant surgery, there was steady progress in language development for TD allowing for an increase in spoken communication between the twins. For example, TD would ask TNH to read a storybook to her. They would sit together on a chair, looking at the pictures, discussing what was happening and what they saw. They would have discussions about the food they were eating and games they were playing.

Field Notes and Observations

Table 1 provides a summary of the field notes and observations of the twins’ expressive language development with a focus on the 8-month period from age 1.7 to 2.3 years. At 1.7 years, TNH demonstrated a larger expressive vocabulary than TD and was using three word utterances, which included the use of nouns. TD, with a postimplant age of 6.5 months, had fewer words, most of which were nouns. Even at 2 years of age, TD was still using utterances primarily from Brown’s early stages (Brown, 1973). She was primarily using the language functions of nomination (naming objects, people, etc., such as “ball” and “Olivia”) and recurrence (more my turn). But as the table indicates, TD continued to expand her expressive lexicon as she gained more experience with listening. At 11.5 months postimplant, she began to speak in one to three word utterances and was using more sophisticated syntactical structures (e.g., “I want to do it,” “I want more tape”).

At 1.7 years (when TD had a hearing age of 6.5 months), TNH demonstrated the ability to maintain greater attention during book reading. She looked at pictures, labeled objects in the pictures, and repeated words and sounds. TD paid less attention to storybooks and did not repeat words or sounds. During one particular session, TNH was immersed in the storybook for 30 min, turning pages and looking at pictures. TD, on the other hand, went to play with toys. During playtime, TNH’s vocalizations were jargon-like with real words in comparison to TD whose vocalizations consisted of sounds and cooing. However by 1 year 11 months of age (11 months postimplant) TD was labeling objects in pictures, was attentive to the story, and demonstrated more attention to the storybook. She was talking in jargon-like sentences using some real words.

Formal Assessments

The LDS was administered five times to TD and once to TNH (see Table 2). Preimplant TD’s expressive and receptive language development is not typical for her age. By 3 months postimplant, she had age-appropriate receptive language, but she was just below age appropriate for expressive language. Eight months postimplant, her receptive language continued to develop appropriately, whereas her expressive language was 5 months below age-appropriate levels. At 10 months postimplant, language development, both expressive and receptive, was within the normal range. At 27 months of age, 15 months postimplant, TD
<table>
<thead>
<tr>
<th>Date</th>
<th>Age (years)</th>
<th>Hearing age</th>
<th>TNH</th>
<th>TD</th>
</tr>
</thead>
</table>
| September 27, 2006  | 1.7         | Postimplant 6.5 months | • All done  
• Baby  
• Bunny  
• Bike  
• Ba (ball)  
• Books  
• Bye bye  
• Bird  
• Ca (car)  
• Duckie  
• Daddy  
• Faster  
• Good  
• I da ut  
• I dic it  
• I'll tak it  
• I done  
• Juice  
• Look  
• Mama  
• More  
• Nose  
• No  
• Ok  
• Plane  
• Puppy  
• Two  
• Three  
• Up  
• Wow  
• ya | • a  
• ba ba  
• Baby  
• Ball  
• da  
• Dirty  
• Eye  
• More  
• Oh oh  
• wawawa  
• ya (using “ba” for more than one thing) |
| December 7, 2006    | 1.9         | 9 months NR | • Eyes  
• Green  
• Olivia  
• Out  
• Teeth  
• Yellow  
• Yes  
• Oh-oh | • Red  
• Star  
• Tree  |
| December 21, 2006   | 1.10        | 10 months   | • Red  
• Star  
• Tree  | • My picture  
• Who is that  
• Baby bipop  
• Bunny  
• Kitty cat  
• Bear  
• Green  
• On my shirt  
• Purple  
• I want crayons  
• I want some paint  
• Mommy and daddy picture | • I do it  
• Red  
• Owl  
• Bear  
• Green  
• Ooh fell down  
• Bunny  
• Cat  
• Meow meow  
• Brown  
• Shoes  
• All done |
Table 1  Continued

<table>
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<tr>
<th>Date</th>
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<th>Hearing age</th>
<th>TNH</th>
<th>TD</th>
</tr>
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<tbody>
<tr>
<td>March 22, 2007</td>
<td>2.1</td>
<td>1.1</td>
<td>I want color</td>
<td>Don’t touch that</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I want blue</td>
<td>More my turn</td>
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<td></td>
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<td>Dot</td>
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<td>More</td>
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<td>Stuck</td>
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<td>Snow</td>
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<td>Bunny</td>
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<td>Sh sh sh</td>
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<td>Ohoh down</td>
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<td></td>
<td>I want glue</td>
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<td>Samantha’s turn</td>
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<td>Stickers</td>
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<td>Its stuck</td>
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<td>April 4, 2007</td>
<td>2.1</td>
<td>1.1</td>
<td>My turn</td>
<td>My turn</td>
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<td></td>
<td></td>
<td></td>
<td>I don’t like it</td>
<td>Duck</td>
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<td></td>
<td></td>
<td>Monkey</td>
<td>Quack quack</td>
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<td></td>
<td></td>
<td>Open</td>
<td>Bird</td>
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<td>Fish</td>
<td>Cow</td>
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<td></td>
<td>Dots</td>
<td>Moo moo moo</td>
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<td></td>
<td></td>
<td>In the basket</td>
<td>Around</td>
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<td></td>
<td>Same/different</td>
<td>All done</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>My juice</td>
<td>Cat</td>
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<td></td>
<td></td>
<td></td>
<td>Its on the floor</td>
<td>Meow meow</td>
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<td>Yellow</td>
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<td></td>
<td></td>
<td></td>
<td>Blue</td>
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<td></td>
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<td></td>
<td></td>
<td>Same/different</td>
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<td></td>
<td></td>
<td>Bunny</td>
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<td></td>
<td></td>
<td>This one</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>More stickers</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>Open</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>I want to do it</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>All animals</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>All animal sounds</td>
</tr>
<tr>
<td>April 19, 2007</td>
<td>2.2</td>
<td>1.2</td>
<td>I got a hair cut</td>
<td>Cathy’s here</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I want to stir it</td>
<td>I want more tape</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No, I am going to do it</td>
<td>I want more tape</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I want the horsie</td>
<td>Green</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I want another animal</td>
<td>It green</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>My pig is in the mud</td>
<td>Blue</td>
</tr>
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<td></td>
<td></td>
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<td></td>
<td>Purple</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Brown</td>
</tr>
<tr>
<td>June 7, 2007</td>
<td>2.3</td>
<td>1.3</td>
<td>I want more tape</td>
<td>Bye-bye Cathy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I want to see it</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>I like the peanuts</td>
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<td></td>
<td></td>
<td></td>
<td>I’ll put some on it</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>I’ll put my paints away</td>
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</tbody>
</table>

Note: TNH, twin girl with normal hearing; TD, twin girl born deaf.
continued to maintain expressive and receptive language at age-appropriate levels. The LDS indicates TNH as performing well above age-appropriate levels, with expressive and receptive language scoring a minimum 5 months above her chronological age.

The PLS-4 was administered only to TD (see Table 3). At a chronological age of 2.9 years, TD’s scores indicated her language to be age appropriate for both expressive and receptive language. Her AC score was 3 years 7 months and her EC score was 3 years 1 month, indicating that both comprehension and communication are well above age-appropriate levels. More striking is that TD’s expressive language was 4 months above the mean for her age, whereas her AC exceeded the mean by 10 months.

Language Samples

The language sample analyzed below was collected at the completion of the study when the twins were aged 2 years 10 months and TD had a hearing age of 1.9 years. Observations are presented using categories from the Tait video analysis.

**Asking questions.** TNH demonstrated the ability to ask the researcher “what,” “why,” “can,” and “yes/no” question formats such as “Is it ___________?.” TD demonstrated beginning production of “Did you ____?,” “can,” and “what” question forms.

**Receptive vocabulary.** TNH demonstrated understanding of some adjectives (e.g., striped), sophisticated prepositions (e.g., under, on top of), and the concepts of “day and night.” TD demonstrated the understanding of basic prepositions (e.g., under, in, to, on), some adjectives (e.g., striped, another), some homonyms (two, to, too), synonyms (sleepy/tired), auxiliary verbs (should), and conjunctions (but, and).

**Question forms.** Both girls responded to simple forms of “why” and “where” questions, often responding to “where” questions by answering “here” and “there.” They correctly answered simple and more complex forms of “what” and “who” questions. In addition to “WH” questions, TNH replied to questions beginning with “can” and “how many.” Both twins responded to yes/no question forms as well as questions involving two choices (e.g., “Is it __ or ___?”). Often, TNH affirmed the question asked to her by repeating what was originally asked and elaborating on her previous answer.

**Follow instructions.** TNH and TD followed single-step directions for the duration of our interaction.

**Unknown expressive vocabulary.** When TNH was presented with a question or given an instruction that she did not understand or could not respond to, she employed strategies to indicate she needed assistance. She would stare at the picture/object, look inquiringly at the speaker, or point to the visual in question. TD also had strategies for dealing with confusing questions or instructions. She pointed, looked at the visual,
but unlike TNH, she usually remained looking down and did not respond. The Tait video analysis procedure codes interactions in which the child responds without looking up at the speaker as “non-vocal looking turns.”

Social interaction. Both girls exhibited good joint attention during the one-on-one sessions.

Reading readiness. TNH and TD demonstrated appropriate reading readiness skills (e.g., turned pages in order, pointed to pictures on request, responded to questions about the story).

Expressive language. TD showed the use of reflexive pronouns. She was beginning to produce “Did you?” questions. She was able to use prepositions such as under, in, to, on, at. TD was unable to express her thoughts in complex sentence structures. The girls manifest social, interactive, and communicative skills when engaged with another person. They initiated conversations, were able to stay on topic, change topics, rephrase to clarify, turn take appropriately, and ask for clarification from the speaker.

Taken together, the four data sources yielded consistent results. First, it is clear that there are differences in the rate and pace of language development between the twins. From the outset, TNH appeared to be functioning above her age peers in both expressive and receptive language, whereas TD (preimplant) was lagging behind both her sister and her age peers. Post-implant, TD evidenced steady and consistent development in both receptive and expressive language to the point that she achieved age-appropriate performance relative to hearing age norms. That said, she continued to be outpaced by her twin sister, although this must be qualified by the fact that TNH was performing above age norms. Overall, the most important finding of this analysis is that TD achieved receptive and expressive language levels that were comparable to her hearing age peers.

Discussion and Implications

The primary goal of this study was to examine the language development of a pair of fraternal twins—one deaf and one hearing—with the deaf twin receiving simultaneous bilateral cochlear implants at 1 year of age. Expectations were that the deaf twin, as a consequence of early bilateral implantation, would exhibit less language delay than is typical in children born with profound hearing loss.

The results reported support these expectations. Preimplant, TD’s language was delayed compared to her hearing twin and to the established norms for her age. Even at the age of 19 months (7 months postimplant), TD continued to trail her hearing sister in both vocabulary and articulation. But within 4.5 months (at 23.5 months), TD had developed receptive and expressive language abilities equal to what TNH had exhibited at 19 months.

Results from the LDS indicated that TD had age-appropriate receptive and expressive language just 11.5 months postimplant. Evidence from the PLS-4 demonstrated that her AC and EC surpass age expectations. At a chronological age of 33 months (21 months post-implant), TD’s expressive language is 4 months above age norms, and her AC is 10 months ahead.

These data support findings from previous studies which suggest that successful development of language in children with early-onset deafness is strongly correlated with cochlear implantation before 12 months of age (Dowell, 2005; Ertmer & Mellon, 2001; Lesinski et al., 2006; Marschark, 2007; Nicholas & Geers, 2006; Papsin & Gordon, 2007).

It should also be noted that both girls benefited from a home environment that was optimal in facilitating language development in many ways. The parents were well educated and involved and capably implemented the strategies that were suggested to them by the early intervention team. In addition to the parents, the extended family was also involved and supportive of the girls’ language development. However, it should be noted that, although supportive, these factors alone are not sufficient, nor do they guarantee appropriate language development in a child with hearing loss.

Access to language is a most critical component and this was afforded by the cochlear implant, allowing for all the conditions for language acquisition to be met. This ready access to language allowed TD to benefit from interactions with her hearing sister who
provided a strong language model. As twins, they participated jointly in most daily interactions (e.g., bathing, dressing, playing together), and this provided multiple opportunities for meaningful, rich interaction. These interactions were enhanced by the fact that TNH was such a capable communicator who took the lead in interactions often answering the questions that TD asked.

Although these results are compelling, a major limitation is the size of the study. This is a single case study and additional research needs to be done to see if these results will be seen with other children. Bilateral cochlear implantation was relatively new at the outset of this study, with TD being one of the first five to undergo this surgery in the province in which she lives. As greater numbers of children receive bilateral implants, it will be possible to track development in this population. This is an area of the field where the research is still in its infancy and the challenge will be to track not only early language development but later development of both language and early literacy.

It remains the case that relatively little is known about the initial stages of language development in children who are implanted before their second birthdays (Ertmer, Strong, & Sadagopan, 2003). This can be explained by the fact that the minimum age requirement for implantation was lowered from 18 months to less than 12 months just within the last several years. Thus, few young implant recipients have been available for research purposes until recently. It is also the case that it is difficult to involve deaf toddlers in formal testing procedures. Their early language gains must be measured through behavioral observations until they are capable of responding appropriately under structured testing conditions. This can be a challenging and time-consuming endeavor. That said, in future studies, it would be useful to include additional measures of language development (e.g., MacArthur Communicative Development Inventories [Fenson et al., 1993]) to provide thicker descriptions of childrens’ progress over time and to allow for richer comparisons among participants.

In sum, there is a pressing need for additional research in the area of bilateral cochlear implantation in children from 1 to 3 years of age. This study is an effort to address this gap. In demonstrating that a deaf twin with bilateral implants is functioning at a language level on par with her hearing age peers, a strong case can be made for the positive impact of this intervention—an intervention that will play an increasingly significant role for children born with profound hearing loss.

Notes

1. These are the communication options offered by Infant Hearing Program in the province where the family lives http://www.mountsinai.on.ca/care/infant-hearing-program/families-and-caregivers-1/communication-development.

2. The PLS-4 was not administered to TNH as she was performing at age-appropriate levels. In future studies, we would administer this assessment to all participants to more accurately report and compare progress.

Conflict of Interest

No conflicts of interest were reported.

References


