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Learning to Use the Cochlear Implant: A Child Who Beat the Odds

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Thousands of children have received cochlear implants since the Food and Drug Administration (FDA) approved the device in 1990. Researchers have learned a considerable amount regarding the auditory and speech production skills that children who are prelingually, profoundly deaf develop after they receive a cochlear implant. Speech production and language outcome data indicate that there is wide variability in skill levels (Tye-Murray, Spencer, & Woodworth, 1995).

Current research efforts have attempted to make predictions regarding which children are most likely to progress in their speech recognition and speech production skills following receipt of a cochlear implant. Researchers have identified characteristics that may predict eventual success with the cochlear implant. Hellman et al. (1991) suggested that the following variables are influential: age at implantation, duration of deafness, medical/radiological findings, multiple handicapping conditions, functional hearing ability, family structure and support, expectations of the family (parents and child), educational environment, and availability of support services. In addition, Fryauf-Bertschy, Tyler, Kelsay, Gantz, and Woodworth (1997) reported that consistency of wearing time is associated with improved ability to recognize closed-set words.

Cochlear Implant Candidacy Issues

There are no cookbook procedures to follow when determining whether a child is an appropriate candidate for receiving a cochlear implant. Once it has been determined that a child meets the audiological criteria (currently a profound, bilateral hearing loss and minimal or no speech recognition skill), the members of a cochlear implant team will evaluate other factors that might have an impact on the child's successful use of the device. In particular, they evaluate whether the child's family is willing and able to commit time and effort toward making the cochlear implant a successful communication aid, and whether they have realistic expectations. The child's educational placement is also assessed. Ideally, the child's educational placement will provide abundant auditory speech stimulation during the school day (Tye-Murray, 1993; Zwolan, Kileny, Zimmerman-Phillips, & Telian, 1996). If the assessment is negative on any of these issues, the team may recommend against implantation.

Purpose

This report presents a case study in which a young child has made good progress with a cochlear implant, despite the presence of family and school-related concerns before implantation. Although potent predictors have been identified, this study demonstrates how difficult it is to determine a priori who will be a successful cochlear implant user and who will not.

History

Jane Smith (a pseudonym) was referred to the University of Iowa Hospitals and Clinics at the age of 4 years and 10 months as a candidate for a cochlear implant. She was born with normal hearing, but at the age of 10 months, she contracted spinal meningitis and became profoundly deaf. Jane, the youngest of four children, had three sisters between the ages of 4 and 12 when she lost her hearing. Jane's father was a bus driver, her mother was in sales, and

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the parents both spent considerable time away from the family. The oldest sister and the maternal grandparents helped with child care. Jane's parents expressed the concern that although they were willing to learn sign language, it was challenging for them because they felt that they had limited practice time. The oldest sister, who was 16 at the time of Jane's initial implant evaluation, had become more proficient at communicating with Jane, and she usually served as the interpreter between Jane and the rest of the family.

Educational Placement

Four months after Jane lost her hearing, educational support began with home visits from an early childhood specialist with the area education agency. These services included sign language classes for the family and home-bound speech-language treatment services for Jane. At the age of 3 years, Jane entered a preschool, multicategorical program. The program was not designed for children who were hearing impaired, but her preschool teacher knew some signs. Speech-language therapy services continued three times a week within a small group. Sessions lasted between 15 and 30 minutes each. Goals of these sessions included vocabulary development and speech sound development. Jane was seen for her preimplant evaluation during the spring semester of preschool and was to begin kindergarten in the fall.

Preimplant Evaluation

Auditory test results just prior to implantation indicated that Jane (age 5) had a profound, bilateral sensorineural hearing loss. Left ear pure-tone test results revealed no responses across all frequencies, and right ear pure-tone results revealed a 105 dB threshold at 250 Hz, and a 115 dB threshold at 500 Hz. Her performance on all speech perception testing was below chance level as she was unable to respond to the tasks. This evaluation indicated that Jane was an audiological candidate for an implant. The family was then given information regarding the cochlear implant team evaluation, which included a medical evaluation with a computerized tomography (CT) scan, a psychological evaluation, and a speech and language evaluation.

A psychological evaluation was scheduled and completed at the following preimplant visit. The Leiter International Performance Scale (Leiter, 1969) and the Hiskey-Nebraska Test of Learning Aptitude (Hiskey, 1966) were administered to assess intellectual functioning. On the Leiter, Jane achieved a score of 103, which was well within the average range. On the Hiskey-Nebraska, she achieved a learning quotient of 114, which indicated that her intelligence was within the high-average range. Behavioral observations revealed that Jane separated easily from her parents, but that she was somber and withdrawn and appeared to have difficulty understanding what was signed to her. She rarely smiled and had a flat affect. The examiner reported that Jane was largely removed from her parents and rarely engaged in communication attempts with them. During a play session, for example, the mother spent most of the time talking to the examiner who was videotaping or looking at the instructions for a Play Doh toy while Jane played with the toy. In some instances when attempting to communicate, Jane would sign with her hands under the table, and she made little eye contact. Jane's mother tended to use her voice exclusively and made very little eye contact. When the mother used signs, she did not always gain Jane's attention first. The cochlear implant team speculated that neither Jane nor her parents had come to develop the communication skills that allowed them to feel comfortable in communicative situations with each other, and in a sense they communicated as if they were strangers. During the initial evaluation sessions, Jane's sister was not present to serve as their "interpreter." Reports from the school indicated that Jane was slow to warm up to new people and that even after she became familiar with people, she was described as quiet.

The parents completed the Minnesota Multiphasic Personality Inventory-2 (MMPI-2, Greene, 1980). Jane's mother's responses to this inventory indicated that she approached the task with defensiveness and that her responses may have been less than candid. The profile suggested that she lacked flexibility and had a poor tolerance for stress and pressure. Jane's father's responses indicated that he was markedly evasive, rigid, and stubborn, and that he might be difficult to work with.

Preimplant speech and language testing revealed that Jane was producing some sounds in conjunction with her signs. She tended to use one- or two-word utterances in a story retell task, and her mean length of utterance was 1.8 words. Her phoneme repertoire consisted of the following sounds: /b, m, w, j, ʌ, ɪ, æ, eɪ, ʊ/. Jane required considerable prompting to produce signs or vocalizations, and spontaneous communication attempts were minimal.

Candidacy Concerns at Initial Evaluation

The following areas were of a concern to the members of the cochlear implant team and were discussed during the team meeting: family support, parents' level of communication and interaction with Jane, and educational programming and availability of support services.

First, psychological testing indicated that the parents might not be reliable reporters regarding Jane's progress with the cochlear implant and that this might make it difficult to work with them. It was speculated that the parents felt that they needed to please the implant team in order for Jane to be selected as a candidate. Efforts were made to assure the parents that it was important for them to provide candid answers so that the team could help Jane in the most effective way possible.

Second, the parents had limited communication and interaction with Jane, and there was concern that they would not provide adequate language models or communication partners for her as she learned to use the device. Jane's oldest sibling had plans to leave home within the next 2 years, and she was the main source of communication between Jane and her parents. This impending event increased the need to promote direct communication between Jane and the parents.

Finally, there was concern regarding educational programming and availability of support services. The family lived in a small town in a rural setting. The school was providing minimal support services for auditory training. School personnel stated that they would have a difficult time finding an educational interpreter for Jane's upcoming kindergarten year. For kindergarten, the program would include placement in a mainstream classroom with 3 hours of service per week from an itinerant teacher of the hearing impaired.

Within the school staff, there were varying levels of support for the cochlear implant itself. Two key personnel stated that they did not feel that Jane was a good cochlear implant candidate. The teacher of the hearing-impaired displayed concerns regarding the implant. She was an advocate for the preservation of Deaf culture, encouraged the use of sign language, and put little emphasis on auditory training. This was a concern because follow-up auditory training and development of a positive sense of self for the child were considered to be intrinsic to the success of the cochlear implant program. Another teacher had specific concerns regarding the parents' ability to ensure that Jane wore the device, citing times when Jane had arrived at school without proper winter clothes. There was also concern that the parents had not fully accepted Jane's deafness and that they had unrealistic expectations that the cochlear implant would restore hearing and permit rapid speech acquisition.

A meeting with the parents and school personnel was held, and members of the cochlear implant team provided a forum for these concerns. Although no formal plan was made, it was agreed that the family and school would address the problem areas. Specifically, the school agreed to hire an educational sign language interpreter who would use Signed English for the kindergarten year and subsequent years. The speech-language pathologist and the itinerant teacher were given an in-service regarding auditory training and the technical aspects of the cochlear implant.

The decision to proceed with the cochlear implant surgery was made on the basis of the understanding that the speech-language pathologist and the teacher of the hearing impaired would address auditory training and facilitate use of the device during the school day. The parents were also encouraged to continue to learn sign language and to attend the parent training seminar offered by the cochlear implant center. A follow-up to these concerns is presented in the section regarding factors that influenced progress.

Performance Over Time

Jane's progress in the areas of auditory perception, speech production, and language acquisition was monitored at yearly intervals or more frequently over a 4-year period postimplant. Sound field testing results are presented first. Jane's sound-detection levels with the implant were measured in the sound field at regular intervals from the time of the initial implant stimulation. After approximately 4 months of implant use and five speech processor mapping sessions, Jane's sound field detection levels ranged from 20 to 30 dB HL across octave frequencies from 250 Hz to 4000 Hz. Over the 4-year follow-up period, there was very little variation in these thresholds. Jane consistently preferred to use a relatively high setting on the speech processor microphone sensitivity.

Perceptual testing was completed at yearly intervals and will be presented in a hierarchy from nonlinguistic test results to open set linguistic test results. Test scores at the preimplant visit were all below chance level. Results from 1 year through 4 years postimplantation can be found in Table 1. The Sound Effects Recognition Test (SERT, Finitzo-Hieber, Matkin, Chero-Skalka, & Gerling, 1977) is a four-choice picture test of environmental sounds. Pattern perception testing included the Monosyllable, Trochee, Spondee Test (MTS, Erber & Alencewicz, 1972), which is a discrimination task of 12 words: 4 single syllable, 4 trochee, and 4 spondee words. Recognition of two-syllable words was tested via the Four Choice Spondee and Monosyllable tests from the CID Early Speech Perception Test Battery (Geers & Moog, 1990). This test required discrimination of a word or syllable from a set of four choices. Recognition of monosyllables based on vowel perception was completed via the Children's Vowel Perception Test (Tyler, Fryauf-Bertschy, & Kelsay, 1991b), a four-choice test of five sets of words varying in vowel place and height. The Word Intelligibility by Picture Identification (WIPI, Ross & Lerman, 1971) required the

TABLE 1. Perceptual testing results.

	Percent Correct Scores Months Post Implant				
Test	0	12	24	36	48
Sound Effects Recognition Test (SERT)	UA	35	55	65	NA
Monosyllable, Trochee, Spondee (MTS)					
Word	UA	8	83	83	100
Stress	UA	25	88	88	100
Central Institute for the Deaf (CID) Four Choice Spondee and Monosyllables*	UA	42	79	92	100
Vowel Perception Test	UA	35	83	90	95
Word Intelligibility by Picture Identification (WIPI) Test					
Sound	UA	20	44	72	80
Audition + vision	UA	50	70	88	96
Audiovisual Feature Test					
Audition-only	UA	10	20	40	53
Audition + vision	UA	23	53	80	83
Vision-only	UA	12	28	38	25
Phonetically Balanced Kindergarten (PBK)					
Words	UA	0	4	28	30
Phonemes	UA	0	19	56	58

* subtests of the CID Early Speech Perception Test Battery
NA = not administered
UA = unable to complete the test

recognition of one of six phonetically similar words. This test was presented in auditory only condition and auditory plus visual condition. Recognition of monosyllables based on perception of the consonant was assessed by the Audiovisual Feature Test for Young Children (Tyler, Fryauf-Bertschy, & Kelsay, 1991a). In this test, 10 consonant sounds are included and are administered in auditory only, vision only, and combined conditions to assess the child's lipreading enhancement from the implant. Finally, open set identification of monosyllables was completed via the Phonetically Balanced Kindergarten Word List (PB-K, Haskins, 1949).

Jane achieved good sound detection levels for speech and warble tones across the frequency range. Her performance on the perceptual test battery showed continued improvement in speech perception skills across almost all tests. On the Audiovisual Feature Test (Tyler, Fryauf-Bertschy, & Kelsay, 1991a), Jane's scores on the vision-only subtest demonstrated a decrease in accuracy from the 36-month interval to the 48-month interval and a marginal gain in the sound plus vision condition. These results may indicate that she is becoming less facile in using visual information. Her scores for the PB-K test also may indicate that she is approaching a plateau in performance for this test. She is beginning to achieve the highest score possible for many perceptual tests. In summary, she receives excellent audiological benefit from the cochlear implant.

Speech production test results are reported in Table 2, and include preimplant test results through 4-year results. The Fundamental Speech Skills Test (FSST, Levitt, Youdelman, & Head, 1990) provided an assessment of phonatory, respiratory, and prosodic aspects of speech. Jane's scores demonstrate that she made rapid progress with her ability to maintain her breath stream, use an appropriate pitch, and produce the correct number of syllables. She is currently beginning to produce syllabic stress and use intonation contours. The test of phoneme production accuracy, the Short-Long Sentence Repetition Test (Tye-Murray, Spencer, & Woodworth, 1995), required Jane to repeat a total of 14 sentences after the examiner. The task was videotaped and then phonetically transcribed. Results indicate a notable increase in phoneme production accuracy, from 10% phonemes correct at the preimplant interval to 83% phonemes correct after 48 months. Accuracy in word production increased from 0% to 65% words correct (in order for a word to be scored as correct, all sounds had to be articulated correctly).

To gain an idea of how much Jane was using her voice at each yearly test interval, the percent of words she produced using sign only and voice-plus sign was calculated during the first 100 words produced in a story retell task. Before she received her implant, Jane used her voice in conjunction with sign for 50% of the words she produced. After 4 years of implant experience, Jane used her voice in conjunction with sign for 99% of the words she produced.

To gain an inventory of Jane's phoneme repertoire, a phonetic transcription of a story retell task (Tye-Murray, Spencer, & Woodworth, 1995) was completed. In this task, the speech-language pathologist used speech and Signed English to describe a short story on the basis of picture sequence cards. Jane then retold the story. A total of six stories were administered at each 12-month interval. Jane's responses were orthographically and phonetically transcribed. Phoneme repertoire was derived from the first 100 words of the transcription. Growth in phoneme repertoire is shown in Table 3.

Table 4 displays results from language testing. All six story transcriptions from the story retell task were used to assess language development. Two language measures were derived from this task: a mean length of utterance (MLU) and an index of productive syntax (IPSyn) score (Scarborough, 1990). MLU in words was computed by dividing the total number of words by the total number of utterances. MLU increased each year and has not begun to asymptote. The sharpest increases occurred between the 12-month and the 24-month interval. The IPSyn score is a measure of grammatical complexity that reflects the emergence of syntactic and morphological types. In this scoring system, a point is awarded for up to two occurrences

TABLE 2. Speech production test results.

	Months Post Implant				
Test/Subtest	0	12	24	36	48
Fundamental Speech Skills Test					
Breath stream	0	12	100	100	100
Elementary articulation	31	63	94	100	100
Pitch	79	96	100	100	100
Syllabification	17	28	100	100	100
Stress	6	11	72	83	83
Intonation	0	8	42	75	50
Short-Long Sentence Repetition Test (short form)					
% phonemes correct	10	NA	49	58	83
% words correct	0	NA	16	21	65

NA = not administered

TABLE 3. Phoneme repertoire development.*

Months Post Implant	Phonemes
0	ʌ, ɪ, æ, eɪ, ʊ, b, m, p
12	ʌ, ɪ, u, æ, ɑ, oʊ, ɛ, p, b, n, m, w
24	ʌ, ɪ, u, æ, oʊ, a, ɛ, eɪ, ʊ, p, b, m, k, h, w, f, ʃ, d, t, g, j, n
36	ʌ, ɪ, u, æ, oʊ, a, aɪ, ɛ, ʊ, p, b, t, d, θ, ʦ, s, k, f, l, w, j, n, m
48	ʌ, ɪ, u, æ, oʊ, a, aɪ, ɛ, ʊ, ɚ, ɔi, au, eɪ, p, b, t, d, θ, ʦ, s, z, k, f, v, l, h, j, m, n

*The phonetic inventory was obtained by phonetic transcription of a story retell task.

TABLE 4. Language analysis results of story retell data.

	Months Post Implant				
Analysis	0	12	24	36	48
MLU	1.8	1.6	4.9	6.2	7.4
IPSyn score					
Noun phrases	5	4	19	19	20
Verb phrases	9	5	17	23	20
Questions/negations	0	0	0	3	3
Sentence structure	8	6	16	22	26
Total	22	15	52	67	69

of 56 forms, and the total count is used as the summary score. Thus, the IPSyn is a measure of the use, rather than the misuse, of a particular grammatical form. As such, it is a measure of the emergence rather than the mastery of syntactic and morphologic capabilities. Subscores of the IPSyn include noun phrases, verb phrases, questions and negations, and sentence structures. Each sentence from the story retell transcription was coded and scored for each interval tested.

These results indicate steady progress in Jane's ability to listen, understand, and produce sounds and words. Her phoneme repertoire expanded, her accuracy of phoneme production increased, and she developed the ability to maintain her breath stream and use her pitch to convey meaning effectively. Her test scores on the FSST indicate that she attained the highest level for all subtests with the exception of producing the correct stress within words and in producing the correct intonation patterns for sentences. Her MLU and the complexity of her grammatical structures consistently increased. Annual reports indicate that Jane became increasingly animated and communicative with each year of experience. At her 48-month interval checkup, Jane achieved grade-level work in school. Her educational placement was full time within the mainstream, with an interpreter for all of her academic classes. She received individualized tutoring from her interpreter for difficult class work, and she also received reading support from the reading specialist. She was out of class twice a week for 20 minutes each time for speech treatment.

Factors That May Have Influenced Progress

Several factors may have contributed to Jane's progress, including an increase in the family's involvement and acceptance level, community support, educational placement, and rapid improvement in auditory skills. Jane had hearing for the first 10 months of her life, and this may have increased her ability to use the information she received via the implant. Her improvements were fairly rapid from year to year—much the same as those of other children who have become our most successful users.

Regarding family support, the implant staff felt that although they advocated for more school services, they had minimal involvement with Jane at the onset and limited understanding of many issues regarding deafness and educational programming. This concern was addressed by the center. For example, both parents attended a 2-day parent seminar offered by the implant center. In this seminar, a small group of parents participated in interactive sessions that dealt with topics such as incorporating auditory training into daily activities and learning about speech and language development skills. The seminar also used parent-generated group discussions to address issues such as working with educators and dealing with stress.

Jane and her parents also participated in a pilot 8-week home training program developed at the implant center (Tye-Murray & Kelsay, 1993). They took home a computer equipped with a laser videodisc player, a touch screen, and specialized video training software. The parents also received workbook activities that were designed to increase knowledge about how children learn to hear with an implant that were to be mailed back each week and (Kelsay & Tye-Murray, 1993). The program was monitored with weekly calls and mail-in response forms. Unfortunately, the parents did not consistently comply with the program. For example, they did not always ensure that Jane did her speech-reading computer exercises. Because the parents did not always send back their own workbook exercises, it is not known how much they read or benefited from the information contained in the workbook.

Regarding community support, a local newspaper wrote a story that featured Jane, her surgery, and her use of sign language within the classroom. This publicity generated community support for her, and a fund-raiser was organized that was successful in securing enough money to help pay for a 6-week summer residential program that targeted aural rehabilitation and intensive speech and language therapy. The funds raised enabled Jane to attend this program between the summers of her second and third year of implant experience and again the following summer.

Jane's educational placement was within a mainstream program. This placement allowed her to hear the teacher and other children speak throughout the day, but she had access to an interpreter. This arrangement provided an auditory and language-rich environment. None of the disciplines within her educational programs specifically targeted auditory training at length, however, and Jane's case may be an example of informal auditory learning. The authors are not advocating withholding formalized auditory training; we do not know how well Jane would have done had she received formal auditory training. Jane's interpreter made sign language instruction available to the children in Jane's classroom, and many of her classmates learned sign language and became active communicators with Jane, using both voice and sign. An average of 1 hour of speech therapy services was provided per week through the school system over the 4-year period. No private speech treatment outside of school was provided.

Finally, an interactive effect may also account for Jane's progress. Jane was a child with average to above average intelligence, and her placement in a mainstream educational program enabled her to listen to the language that was produced by children of her own chronological age. This experience may have had a positive effect on her speech production, social skills, and language skills. Her educational program was supplemented in later years by an intensive summer program that targeted speech and language skills more intensively, with some auditory training. In turn, the cumulative effect of increased access to audition may have instigated gains in speech and language skills that made communication between Jane, her parents, and her community more successful.

In summary, this case illustrates how each child who receives a cochlear implant is influenced by a constellation of factors that is unique to that child. Cochlear implant teams need to account for many factors throughout the preimplant evaluation process and as they make recommendations for the use of cochlear implants. In Jane's case, mainstream programming appears to have been beneficial, as it allowed her to interact with hearing peers and listen to the speech they produced. However, mainstreaming may not be an optimal choice for all children.

We do not know how well Jane would have done if she had been educated in a different setting such as a private oral school. We do know that Jane continues to make excellent progress from year to year. Having said that, we must also consider that Jane's progress might have been even more dramatic if she had been given optimal programming factors from the start. It would have been ideal if she had come to us with a cohesive, experienced, and supportive school setting that provided structured auditory training in conjunction with a language-rich environment plus a supportive family network where the parents had established effective communication and were already providing good language and auditory models.

This case makes the point that although we have a good idea of factors that may predict successful implant use in children, the presence of several risk factors should not unequivocally preclude candidacy. Risk factors can be overcome via parent training, school in-servicing, and information provided by the cochlear implant that influences the growth of speech perception and communication skills.

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