Cochlear Implants for Congenitally Deaf Adolescents: Is Open-Set Speech Perception a Realistic Expectation?

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The prognosis for benefit from use of cochlear implants in congenitally deaf adolescents, who have a long duration of profound deafness prior to implantation, has typically been low. Speech perception results for two congenitally deaf patients implanted as adolescents at the University of Melbourne/Royal Victorian Eye and Ear Hospital Clinic show that, after 12 months of experience, both patients had significant open-set speech discrimination scores without lipreading. These results suggest that although benefits may in general be low for congenitally deaf adolescents, individuals may attain significant benefits to speech perception after a short period of experience. Prospective patients from this group should therefore be considered on an individual basis with regard to prognosis for benefit from cochlear implantation.

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Cochlear implants provide significant speech perception benefits to profoundly hearing-impaired children (Dawson et al., 1992; Geers & Moog, 1988; Osberger et al., 1991b). Although the degree of individual benefit varies, a significant proportion of children implanted at an early age may develop an ability to perceive open-set speech through their implant without lipreading (Cowan et al., 1993; Dowell, Blamey, & Clark, 1992). In contrast, children who were hearing impaired from an early age, and who have had a longer duration of deafness prior to implantation, have shown lower scores on most speech perception tests (Luxford, 1989; Osberger et al., 1991a; Staller, Beiter, Brimacombe, Mecklenburg, & Arndt, 1991). Speech perception test results for prelinguistically profoundly hearing-impaired children implanted at or after adolescence suggest that, as a group, these children show less benefit from use of the implant than children implanted under the age of 10 years (Busby, Roberts, Tong, & Clark, 1991; Dawson et al., 1992; Tong, Busby, & Clark, 1988).

Several factors, including age at onset of deafness, lack of early auditory experience, and use of total communication in education, may contribute to the lower range in speech perception scores shown by congenitally deaf adolescents with cochlear implants (Eisenberg, Berliner, Thielemeir, Kirk, & Tiber, 1983; Mecklenburg, 1988; Osberger et al., 1991a; Quittner & Steck, 1991; Staller et al., 1991). Implanted children who use oral communication have shown higher scores on open-set word and sentence tests than implanted children using total communication approaches (Berliner, Tonokawa, Brown, & Dye, 1988; Quittner & Steck, 1991; Somers, 1991; Staller et al., 1991).

Given these results, a realistic assessment of the expected outcomes and candidature of congenitally deaf adolescents for cochlear implantation is appropriate. This report presents results of speech perception evaluations of two congenitally profoundly hearing-impaired children who received a cochlear implant as adolescents. They have demonstrated greater benefits to speech perception than those currently reported in the literature. Although these results are unique to the particular "star" children, and are not indicative of the overall clinical results for this population, they suggest that this group must be considered on an individual case basis.

Methods

Patients

Patient 114 • Patient 114 had a congenital profound bilateral sensorineural hearing loss of unknown etiology. She was fitted with hearing aids from 18 months of age and wore them consistently from this time. Bilateral aided thresholds are shown in Table 1. Patient 114 was enrolled in a total communication program from age 3 until 11, and subsequently attended an oral school. Patient 114 communicated orally and had speech production that was intelligible to listeners experienced in understanding deaf speech.

She received the Minisystem 22 cochlear implant in her right ear at age 13 years 8 months, and had 12 months' postoperative experience at evaluation. She had 22 functional channels in her implant system.

Patient 144 • Patient 144 had a congenital profound bilateral sensorineural hearing loss due to maternal rubella. She was fitted with hearing aids from 16 months of age and wore them consistently (refer to Table 1). Patient 144 attended oral commu-

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TABLE 1. Preoperative unaided and aided hearing thresholds for two patients: unaided thresholds in dBHL *re* ANSI-1989; aided thresholds in dBSPL *re* 20 Pa.

Patient	Frequency (Hz)					
	250	500	1000	1500	2000	4000
Unaided thresholds						
No. 114						
Right ear	100	105	105		115	110
Left ear	100	110	110		115	115
No. 144						
Right ear	100	110	120		NR[a]	NR
Left ear	100	110	110		NR	NR
Aided thresholds						
No. 114						
Right ear	55	55	45	60	75	NR
Left ear	65	50	55	60	60	70
No. 144						
Right ear	55	45	40	45	60	NR
Left ear	65	45	40	55	55	NR

[a] *NR: no response at audiometer limits (120 dbHL).*

nication educational settings from age 2. Patient 144 communicated orally and had speech production that was intelligible to listeners experienced in understanding deaf speech.

Patient 144 received the cochlear implant in her left ear at age 12, and had 12 month's postoperative experience at the time of evaluation. She had 18 functional channels in her implant system.

Assessments

Both children were evaluated preoperatively with hearing aids and lipreading, and postoperatively with the Minisystem 22-channel cochlear implant (Blamey, Dowell, Brown, Clark, & Seligman, 1987; Millar et al., 1992). Both children used the miniature speech processor (MSP), with a formant extraction speech processing strategy called Multipeak.

Test materials were presented live-voice, by a familiar female speaker, at a distance of 1 m, and at an intensity of 70 dBA as measured on a sound level meter. The children were tested in the A (audition alone), LA (lipreading plus audition), CL (cochlear implant plus audition) and C (cochlear implant alone) conditions, and with lipreading alone (L). The children wrote their responses, and feedback was not provided throughout test procedures.

Word-level discrimination was assessed using phonetically balanced open-set PBK Word lists (Haskins, 1949). Half-lists of 25 words were counterbalanced so that neither child was tested with the same list in a particular condition twice, and so that the two children were not tested with the same list in a given condition. PBK Words were scored by the number of phonemes correct, therefore will be referred to as PBK Phonemes hereafter. Patients were tested with one list in each condition.

Sentence-level discrimination was assessed using open-set Bamford-Kowal-Bench (BKB) Sentences (Bench, Bamford, Wilson, & Clifft, 1979). This test consisted of lists of 16 simple sentences that contained 50 key words. Test lists were selected so that no patient was tested with the same list twice. Each sentence list was scored by the number of key words correct. Patients were tested with one list in each condition.

Although patient 114 usually wore a hearing aid with her cochlear implant, results for the CL condition only are presented to facilitate comparison with the results of patient 144. Minimal differences were observed between her CL and CLA (cochlear implant plus hearing aid plus lipreading) results on all tests. No hearing aid alone (A) condition results are presented for patient 114 because she maintained that she could not discriminate any speech with her hearing aid(s) alone, and refused to cooperate with any testing in this condition either pre- or postoperatively.

RESULTS

Table 2 shows speech perception test results for patients 114 and 144. Differences between scores in different conditions were statistically analyzed using the binomial model and the 0.05 level significance table developed by Thornton and Raffin (1978) (see Table 3).

Patient 114 • Scores in the CL condition for patient 114 were high overall; 86% on the PBK Word test

TABLE 2. Summary of results for open-set word and sentence tests for patients 114 and 144. Phoneme scores for PBK Words and word scores for BKB Sentences are in percentage correct. In the condition column, L indicates lipreading, A indicates hearing with a conventional hearing aid and C indicates hearing with a cochlear implant. L and LA data were collected both pre and postoperatively. C and CL data were collected postoperatively.

Condition	Patient 114 (Score %)		Patient 144 (Score %)	
	Preop	Postop	Preop	Postop
PBK Phonemes				
L	65	58	42	54
LA	61	61	81	55
A[a]	—	—	22	3
C	—	45	—	40
CL	—	86	—	91
BKB Sentences				
L	60	44	46	50
LA	86	78	74	60
A[a]	—	—	6	4
C	—	34	—	48
CL	—	96	—	78

[a] *Binaural preoperatively, monaural postoperatively.*

and 96% on the BKB Sentence test. CL scores were also greater than either LA or L scores by 25% and 28% on the PBK Word test and by 18% and 52% on the BKB Sentence test. Patient 114 scored 45% on the PBK Word test, and 34% on the BKB Sentence test in the C condition.

Statistical analysis, shown in Table 3, showed that the differences between CL and L scores were significant ($p < 0.05$) on both tests. Postoperative CL scores for both tests were also significantly higher than postoperative LA scores. Comparison of preoperative and postoperative LA or L scores on both tests showed no significant differences. Comparison of LA with L scores in either the preoperative or postoperative period showed significant differences for the BKB Sentence test both pre- and postoperatively. As mentioned, child 114 would not cooperate for testing in the A condition, so no statistical comparison of C scores with A scores is possible.

Patient 144 • Scores in the CL condition for patient 144 were also high overall: 91% for PBK Phonemes and 78% for BKB Sentences. CL scores were higher than postoperative LA scores by 18%, and were higher than preoperative LA scores by 4% on the BKB Sentence test. On the PBK Word test, the CL score was higher than the postoperative LA score by 36%, and was higher than the preoperative LA score by 10%. In the C condition, patient 144 scored 40% for PBK Phonemes and 48% for BKB Sentences.

Statistical analysis showed that CL scores were significantly higher than L scores on both tests. CL scores were significantly higher than postoperative LA scores on the PBK Word test, but not on the BKB Sentence test. A comparison of LA or L scores between the pre- and postoperative period showed no significant differences. A comparison of LA with L scores in either the preoperative or postoperative period showed a significant difference for BKB Sentences and PBK Phonemes in the preoperative period. A comparison of C and A scores for both tests showed C scores to be significantly higher. There was no significant difference between pre- and postoperative A scores for either test.

TABLE 3. Summary of the results of statistical analysis on the differences in percentage scores on PBK Words and BKB Sentences in different conditions for two patients. In all cases of significant difference, the case mentioned first is significantly greater.

	Significance of difference in scores			
	Patient 114		Patient 144	
Condition tested	PBK Phonemes	BKB Sentences	PBK Phonemes	BKB Sentences
LA vs. L (Preop)	NS[a]	$p < 0.05$[b]	$p < 0.05$	$p < 0.05$
LA vs. L (Postop)	NS	$p < 0.05$	NS	NS
CL vs. L (Postop)	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$
CL vs. LA (Postop)	$p < 0.05$	$p < 0.05$	$p < 0.05$	NS
LA vs. LA (Pre/postop)	NS	NS	NS	NS
L vs. L (Pre/postop)	NS	NS	NS	NS
A vs. A (Pre/postop)	NA[c]	NA	NS	NS
C vs. A (Postop)	NA	NA	$p < 0.05$	$p < 0.05$

[a] *NS = no significant difference between scores at $p > 0.05$ level of significance.*
[b] *p = level of significance of difference in scores.*
[c] *NA = not assessed.*

DISCUSSION

Both children showed significant benefits to speech perception from use of their cochlear implant. They also showed significant implant-alone open-set speech perception benefits on both the word and sentence tests. In addition, both patients demonstrated significant levels of supplementation to lipreading from implant use, and in the case of patient 114, to aided residual hearing. Although the CL postoperative score is not much higher than the preoperative LA score on the PBK Word test, scores in these conditions are both high, and there may be a "ceiling effect" at this level. More importantly, C scores were significantly higher than A scores, suggesting that more speech information was made available through the implant than through hearing aids.

In assessing contributing factors to the unique results for these two congenitally deaf adolescent patients, it has been suggested that early auditory experience is an important factor to successful cochlear implant use in later life (Eisenberg et al., 1983; Dorman, Hannley, Dankowski, Smith, & Candless, 1989; Luxford, 1989). Both patients were aided at a young age and were consistent hearing aid users. Patient 144 did demonstrate a nonzero hearing-aid-alone score preoperatively on both the PBK Word test and the BKB Sentence test. In addition, her LA scores were significantly higher than her L scores preoperatively for PBK Phonemes and BKB Sentences ($p < 0.05$). These results suggest that she was deriving significant benefit to speech perception from residual hearing in terms of supplementation of lipreading, and was also able to obtain a small amount of speech information through her hearing aids alone. It is unfortunate that patient 114 would not cooperate for testing in

the A condition. As a result, we have little indication of how much open-set speech information she received through her hearing aids alone. However, it can be seen from Tables 2 and 4 that her LA scores were overall higher than L scores pre- and postoperatively for PBK Phonemes and BKB Sentences. The differences in scores were significant only for pre- and postoperative BKB Sentences and suggest minimal speech perception benefits from her aided residual hearing at a word level. This is consistent with closed-set preoperative test results in the A condition on the Picture Vocabulary test (33%).

Surveys of the literature (Luxford, 1989; Osberger et al, 1991a; Staller et al., 1991) suggest a more limited benefit to speech perception for patients with a longer duration of profound deafness and/or congenital etiologies. The results for these two patients were much higher than those usually associated with benefits for congenitally deaf adolescents, and were more comparable to speech perception benefits received by children with acquired deafness. Although it is acknowledged that these are "star" performers, and that these results are not indicative of general outcomes of implantation in congenitally deaf adolescents, they provide strong support for the inclusion of this group as candidates for cochlear implantation. The results suggest that these children should be assessed on an individual basis.

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