Multichannel Cochlear Implantation in a Severely Disabled Traumatic Brain Injury Patient: A Case Study

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The cochlear implant has been described in the management of cognitively intact patients with profound sensorineural loss sustained via head trauma. This report will describe our experience with multichannel cochlear implantation in a patient with cognitive and communication deficits 2 years after traumatic brain injury with severe to profound sensorineural loss – with follow-up 2 months, 5 months, and 14 months after implantation.

The cochlear implant is a medical prosthetic device that allows those with profound sensorineural hearing loss to experience hearing sensations. Successful cochlear implantation of postlingually deafened, cognitively intact individuals has been reported as an accepted alternative for management of bilateral profound sensorineural hearing loss (Dowell, Mecklenburg, & Clark, 1986; "NIH Consensus," 1989). During this case study we report our experience with multichannel cochlear implantation in one head trauma patient with cognitive deficits and mild receptive and expressive language deficit.

CASE REPORT

History and Admission Status

M.E., a 26-year-old male and recent college graduate, presented to the Rehabilitation Institute of Chicago (RIC) brain injury unit 23 months after a motor

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vehicle accident sustaining multiple injuries. He suffered an open head injury and spinal cord injury which resulted in paraplegia. He sustained a skull fracture resulting in bilateral VIII nerve compression.

M.E. required a craniotomy for evacuation of a subdural hematoma with subsequent need for placement of a ventriculoperitoneal shunt. He had a history of post-trauma depression and self-harming behavior. He had made one attempt at suicide but at the time he was seen at RIC there was no evidence of suicidal behavior.

On admission to RIC he was reportedly awake, alert, and oriented to person alone. He used a powerful behind-the-ear hearing aid in his right ear. M.E. was easily frustrated, at times impulsive, and he was easily distracted in a noisy environment. His level of reasoning was concrete, and he intermittently displayed socially inappropriate behavior. M.E.'s pattern of thought was tangential at times, but he could be redirected.

M.E. was able to communicate his basic needs and ideas, and he was able to discuss familiar topics via verbal and written communication; yet, he demonstrated a receptive and expressive language deficit which undermined his ability to process auditory-verbal information. He was able to comprehend rudimentary verbal instruction, but he became easily confused when presented verbal information of even moderate abstraction and complexity. He was unable to comprehend and follow multi-step verbal instructions. Comprehension was further compromised by mild-to-moderate response latency, as he was quite slow to respond to environmental information. There was a question as to the contribution his hearing loss played in these observed receptive and expressive language deficits.

M.E. was deficient in his ability to utilize auditory-verbal memory systems. Auditory-verbal memory skills were significantly impaired secondary to his receptive and expressive language disturbance and/or his significant hearing loss. His ability to process oral information was optimized if it could be encoded visually for him. M.E.'s visual-spatial memory was much stronger. His functioning improved when he had written down information he wished to recall. He would also cue others to write down information for him.

M.E.'s interactive communication skills were impaired secondary to hearing loss and receptive and expressive language deficit. To assure comprehension, he repeated everything said to him, and he insisted others speak to him one - word - at - a - time. He carried a lap board and requested written communication to augment auditory-verbal input. Family members also used finger spelling and some isolated signs. While these techniques provided visual input, they interfered with the flow of information and the pragmatic aspects of conversation.

He received psychological counseling previous to his admission and was being treated medically for depression. M.E.'s self-image was severely affected; he needed to learn to live with his physical disabilities as well as learn the limitations of his cognitive status. He complained of social isolation as a result of his hearing loss and tended to ruminate on his hearing impairment.

Because M.E. focused on his hearing loss, participation in therapy was reported to be less than maximal. The need for written communication further interfered with efficient use of therapy times.

Audiologic and Otologic Evaluation

Audiologic evaluation revealed a severe-to-profound sensorineural hearing loss on the right (PTA = 80 dB HL) and no measurable hearing in the left ear. For the right ear a speech awareness threshold of 75 dB HL and a closed-set speech reception threshold of 80 dB HL were obtained. Word recognition at MCL was 0%. Utilizing warble tones in the soundfield, aided-right, audiometric testing revealed responses at 35-45 dB HL for the 500-3000 Hz region. An aided speech awareness threshold of 35 dB HL and closed-set speech reception threshold of 40 dB HL were noted. M.E. was medically stable, and was referred to our center for consideration of cochlear implantation.

Initial otologic examination revealed an obvious left cranial depression defect. The right temporal area was basically normal. Otoscopic examination was normal bilaterally.

The implant team's audiometric evaluation was consistent with previous findings. The remainder of this initial session consisted of counseling M.E. and his family regarding his hearing loss, its effect on communication, and possible alternatives for management. Assistive listening devices were introduced, and communication strategies were explored. A personal FM system was dispensed on a loan basis to help maximize therapy sessions. The process for evaluating candidacy for cochlear implantation was reviewed. This information was shared with his management team at RIC.

Subsequent sessions consisted of an assessment of M.E.'s aided speech recognition ability. Audiotaped subtests of the revised Minimal Auditory Capabilities test battery (Owens, Kessler, Telleen, & Schubert, 1981; *Procedures Manual,* 1991) were administered in the soundfield. Results of testing are summarized in Table 1. Closed set subtests indicated performance better than chance. M.E.'s performance on open set subtests (NU6 and CID sentences) indicated limited understanding of speech. Live-voice speech recognition was assessed via lipreading alone versus lipreading with aided auditory input and revealed a 15% improvement with the addition of auditory cues.

Overall test results confirmed M.E.'s limited recognition of speech, but scores were poorer than expected. However, M.E.'s scores had to be interpreted with caution due to the complicating factors of his receptive and expressive language deficit, decreased cognitive function, and limited vocabulary.

Electrophysiologic Evaluation

Brainstem Auditory Evoked Potentials were absent bilaterally in response to click and tonal (500 Hz) stimulation consistent with bilateral sensorineural hearing loss of peripheral origin. With right ear stimulation, the middle latency response (MLR) was obtained over the vertex and each posterior temporal lobe suggesting intact thalamo-cortical pathways bilaterally.

Radiographic Evaluation

A high definition CT scan (1.0-1.5 mm cuts) of the temporal bone revealed an old fracture involving the left auditory canal and left cochlea. The cochleas were patent bilaterally. An MRI of the brain revealed extensive post-traumatic changes of the temporal lobes bilaterally with damage worse on the left.

Psychologist's Evaluation

Assessment by RIC's clinical psychologist suggested M.E. was motivated and willing to dedicate the effort to participate in the post-surgical training. In addition, it was determined M.E. could deal with and accept the chance of failure.

Promontory Stimulation

Electrical stimulation of the promontory was positive for the left ear in response to square wave pulse trains. Two different frequencies (50 and 200) were tested. Both elicited an auditory sensation and grew in perceptual loudness as stimulus current levels increased.

Counseling

Throughout the evaluation process, M.E. and his family received extensive counseling including education on the function of the normal ear, the patient's hearing loss, the function of the cochlear implant, the operation of the device, the risks of surgery, the post-operative course, and initial stimulation. It was stressed to the patient and his family that the implant processed sound would not be normal hearing. Furthermore, the level of success achieved in previous patients could not be expected with M.E.'s expressive and receptive language deficits, cognitive deficits, and communication skills.

Other issues discussed included the required modification of the surgical flap around a previous incision, and the placement of the internal receiver/stimulator due to an existing shunt. In addition, electrode insertion could be affected by the previous fracture and possible compromise of cochlear patency not detected on CT (Balkany, Gantz, & Nadol, 1988; Wiet, Pyle, O'Connor, Russell, & Schramm, 1988).

Expectation questionnaires administered throughout the pre-operative evaluation process insured that M.E. and his family held realistic expectations, particularly those unique to M.E.'s case, and were adequately informed of the risks and benefits of cochlear implantation and the commitment to the program.

Prior to implantation, M.E.'s hearing aid was upgraded, but he continued to receive limited benefit for speech recognition. Throughout the evaluation process auditory skills continued to be evaluated. With familiarization, M.E. could easily discriminate words of different stress patterns (chicken, cat) by listening. But, he was unable to discriminate between words with similar stress patterns (popcorn vs. baseball). With visual cues he was able to distinguish words of similar stress pattern up to 100% accuracy. He was able to discriminate closed-set sentences of varying lengths but he was not able to discriminate between words with differing second format conformation (fall/feel). Wearing his hearing aid, M.E. was able to make consistent judgments of subjective loudness and comfort levels utilizing warble tone stimuli in the soundfield.

Treatment

It was decided to implant the left cochlea. The team's decision was based on the poor speech understanding despite residual hearing in the right ear, minimal benefit from amplification, and the difference in anatomic damage to the right temporal lobe as compared to the left. Knowing that the majority of auditory nerve fibers cross to the contra-lateral auditory cortex it was hypothesized implanting the left cochlea could have provided greater benefit than with amplification of the right ear. MLR suggested intact central auditory tracts, and the auditory perception upon promontory stimulation indicated there were surviving primary receptor cells in the left cochlea to evoke a response.

The audiologist was confident that M.E. could participate in the psychophysical measures required to set the cochlear implant. In addition to support from the RIC management team and M.E.'s insurance carrier, M.E.'s family support was exceptionally good.

A multi-channel device was fully inserted into the left cochlea, and initial stimulation of the external device took place 6 weeks after surgery.

Rehabilitation

M.E. was successful in communicating his needs and ideas through the use of his working vocabulary. Although he had problems with novel situations, following familiarization training, he was able to follow multistep commands. He was able to make consistent loudness judgments required for programming the device. A consistency of environment, familiarity with the audiologist, and the presence and participation of his family maximized performance during rehabilitation.

Shorter and more frequent rehabilitation sessions were necessary due to M.E.'s medical and psychological complications. In addition, spasticity secondary to the spinal cord injury interfered with retraining; yet, audiologic rehabilitation was considered successful.

Rehabilitation consisted of a hierarchy of auditory and auditory plus visual exercises as well as the development of M.E.'s "memory book." In this book, M.E. logged new vocabulary and his daily care routine. M.E. was introduced to compatible assistive listening devices to enhance communication including a telephone coupling device, personal FM system, and direct audio-input microphone. Role playing and staged "device failures" provided training in communication strategies and troubleshooting. The audiologist from RIC attended all sessions and was instrumental in providing carryover into other therapy sessions.

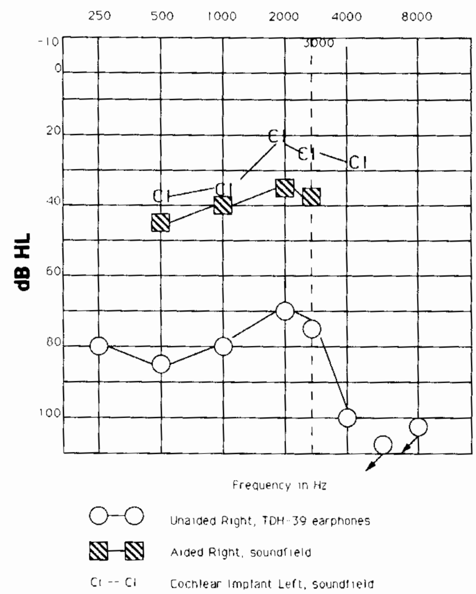

Figure 1. Audiogram pre-operative unaided right, pre-operative aided right, and post-operative cochlear implant left.

POST-OPERATIVE RESULTS

Audiometric and speech recognition testing were performed 2, 5, and 14 months after implantation. Cochlear implant warble-tone thresholds were obtained from 20-35 dB HL for the 500-4000 Hz region allowing M.E. to detect speech at comfortable listening levels. M.E. had a speech awareness threshold of 20 dB HL with the cochlear implant (see Figure 1).

Post-operative open set speech recognition results with the cochlear implant showed a marked improvement in performance compared to pre-operative aided response (see Table 1).

Results on audiotaped closed-set subtests with the cochlear implant (auditory only) showed considerable improvement compared to pre-operative aided scores (see Table 1). The greatest improvement was demonstrated by M.E.'s post-operative cochlear implant open set speech recognition of recorded CID everyday sentences presented in the soundfield. At 14 months post-operative the measure was repeated in the soundfield, hearing aid right alone. M.E.'s performance was similar to his pre-operative aided score. This observation may suggest that improved speech recognition observed post-operatively with the cochlear implant was not due to rehabilitation alone, but to improved processing of auditory information enhanced by auditory input via the cochlear implant.

Post-operatively we also observed improvement in lipreading when combined with auditory input via the cochlear implant (see Table 1). At 5 months and 14

Table 1

Pre- and Post-Operative Speech Recognition Scores (% Correct)

	Pre-Op	2-Month Post	5-Month Post		14-Month Post	
Measures	**HA**	**CI**	**CI**	**HA**	**CI**	**HA**
Closed Set						
Audiotaped condition						
4-Choice Spondee (chance = 25%)	60	85	100		95	
Vowels (chance = 11%)	33	64	78		82	
Open Set						
Audiotaped condition						
NU-6 (word score)	14	14	20		30	
NU-6 (phoneme score)	34	34	47		51	
CID sentences	06	21	33		66	10
Lipreading						
Live-Voice Condition						
CID Sentences						
Auditory + Visual	23	70	70	11	82	24
CID Sentences Visual (lipreading alone)	(08)	(11)	(06)	(06)	(10)	(10)
Gain: Visual + Auditory						
AV score − V Score = Gain	15	59	64	05	72	14

Note. Audiotaped subtests were presented in the soundfield at MCL pre-op and HA post-op and 54 dB HL (approximately 70 dB SPL) CI post-op (*Procedures Manual*, 1991). HA = listening with personal hearing aid set at a comfortable level; CI = listening with cochlear implant set at a comfortable level. Scores in parentheses are lipreading alone.

months post-operatively the lipreading measure was repeated live-voice with M.E.'s hearing aid right plus visual cues and revealed no improvement when compared to pre-operative scores (see Table 1); again suggesting improved speech recognition may be due to improved processing via the implant.

The most productive period of rehabilitation was immediately following initial stimulation. Communication significantly improved with a decreased need to augment oral communication with writing. M.E. continued to be impulsive, but he was redirected orally with ease.

While he initially verbalized disappointment with the quality of hearing through the implant, he used his device all waking hours in combination with his hearing aid from the first fitting date. By 14 months post-implant, M.E. was very positive about the sound he received via the implant.

Residing in an independent living center, M.E. was performing all his self-care skills independently, including the care of his device, by 5 months post-implant. His therapists reported while utilizing the cochlear implant he rarely required words to be presented in isolation, and he discontinued use of a writing lap board. Therapists reported excellent overall progress, attributed in part to M.E.'s enhanced abilities for interaction and socialization with staff and patients. Subjectively, M.E. reported feeling more confident and less isolated. M.E. also reported tinnitus relief post-operatively.

Following post-operative training, M.E. could follow running speech with utterances of 4-6 words in length; by 14 months 8-10 word sentences. He displayed a limited ability to recognize speech without visual cues by 2 months post-stimulation, but improvement was documented at 14 months for open-set measures (see Table 1). Utilizing communication strategies, M.E. was able to use the telephone and to independently employ appropriate communication strategies and assistive listening devices for enhancing communication situations by 14 months post-operative.

DISCUSSION

Determination of an appropriate cochlear implant recipient is not a "cut and dried" issue. To date, protocol and evaluation measures are not available for persons with cognitive deficits sustained in brain injury.

The National Institutes of Health (NIH) consensus statement has made recommendations regarding candidacy ("NIH Consensus," 1989). Traditionally, the most suitable candidate is a healthy "post-lingually, deafened adult exhibiting bilateral, profound, sensorineural hearing loss with aided threshold greater than 60 dB HL, zero percent accuracy in open-set speech recognition, and a lack of substantial increase in lipreading with an appropriately fitted hearing aid." However, the definition of "residual hearing" and "significant benefit from a hearing aid" remains controversial.

M.E.'s aided thresholds were less than 60 dB HL; his lipreading ability of CID everyday sentences improved 15% with the addition of auditory cues from an appropriately fitted hearing aid. Yet, he still had poor open-set aided speech recognition (auditory alone) and felt handicapped and isolated by his hearing loss.

M.E. was not a traditional cochlear implant candidate, and he may not be defined as a "star" performer based on his post-operative speech recognition scores, but his gains 14 months post-operatively exceeded expectations. Benefits M.E. realized were consistent with reported benefits of the multichannel device including: enhanced speechreading ability, enhanced speech understanding without visual cues, and enhanced awareness and identification of environmental sounds. A limited number of patients have the ability to use the telephone without the use of a code (*Audiologist's Handbook,* 1991; Mecklenburg & Brimacombes, 1985).

M.E.'s family reports he has progressed remarkably since implantation; he is a part of family gatherings again, enjoys going to church, and can telephone family members. At 20 months post-operatively M.E.'s case manager reports he is driving an automobile independently and living in his own apartment closely associated with the living center with staffing once per day. She reports employment and independent living are realistic goals for M.E. His current obstacles are social – pragmatic skills and organizational, self-scheduling skills. M.E. states he hears better with his implant. He reports speech is "too low" and "mixed up" with the hearing aid alone. M.E. has stated, "I wish I could have two, one over here (right ear) too."

CONCLUSION

Our experience with multichannel cochlear implantation in one patient with mild cognitive and communicative deficits was, therefore, considered positive. An improvement in objective parameters was observed as well as subjective improvements in quality of life.

The cochlear implant has been used to treat patients with hearing loss sustained via head trauma (Wiet et al., 1990), but implantation in a patient with cognitive and communication deficits has not traditionally been considered.

Patients with bilateral severe to profound sensorineural loss and bitemporal lobe damage should be considered for treatment with a multichannel device when they can cooperate and have the motivation to participate in post-operative retraining.

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