International Journal of Pediatric Otorhinolaryngology (2009) **73**, 189—193

International Journal of Pediatric Otorhinolaryngology

www.elsevier.com/locate/ijporl

What can be expected from a late cochlear implantation?

Maria-Izabel Kos *, Marielle Deriaz, Jean-Philippe Guyot, Marco Pelizzone

Geneva Cochlear Implant Centre, Department of Oto-Rhino-Laryngology, Head and Neck Surgery, Geneva University Hospitals, Switzerland

Received 5 August 2008; received in revised form 6 October 2008; accepted 7 October 2008
Available online 2 December 2008

KEYWORDS
Late cochlear implantation;
Changes in communication mode;
Cued speech;
Outcomes of late cochlear implantation in pre-lingual deafness;
Development of oral communication after delayed cochlear implantation

Summary

Objective: Verify if late cochlear implantation allows pre-lingual deafs to convert from visual to oral communication mode only.
Method: Thirteen pre-lingual profoundly deaf patients implanted the ages of 8 and 22 years were included in the study. Before cochlear implantation, none of the patients used the oral language. Six patients used cued speech and seven used the sign language to communicate. Evaluations were made with measures of hearing thresholds, phoneme identification, categories of auditory performance and rating of the intelligibility of speech before and after implantation. Changes in principal mode of communication (i.e. oral, cued speech or sign language) were also monitored.
Results: The former users of cued speech benefited significantly more from cochlear implantation than the sign language users for phoneme identification and categories of auditory performance, although all had similar hearing thresholds before and after cochlear implantation. After a mean implant use of 4.5 years, four out of six cued speech users converted to exclusive use of the oral language, while only one out of seven former users of the sign language converted to the use of the oral language.
Discussion: It is possible for pre-lingual or congenital deafs to convert totally from a visual to an oral communication mode even in case of late cochlear implantation. Previous awareness of the structure of the oral language, even without hearing (e.g. via cued speech) influences positively the outcome of delayed implantations. We recommend the adoption of oral communication with the cued speech code in cases where a late cochlear implantation is envisioned.

1. Introduction

Cochlear implants have been largely used to restore hearing in pre-lingual deaf children for almost 30 years. A large number of studies have demonstrated

* Corresponding author at: Department of Otolaryngology, Head and Neck Surgery, Geneva University Hospital, Micheli-du-Crest 24, CH-1211 Geneva 14, Switzerland. Tel.: +41 22 372 82 80; fax: +41 22 372 82 40.
E-mail address: izabel.kos@hcuge.ch (M.-I. Kos).

0165-5876/$ — see front matter
doi:10.1016/j.ijporl.2008.10.009

that children implanted after the age of 6—7 years do not obtain as much benefits as children implanted at an earlier age [1—6]. Some studies indicate that although late implanted pre-lingual adolescents develop less speech recognition skills, most of them report satisfaction [7,8]. However it has not been definitively demonstrated that the gain obtained with cochlear implants in pre-lingually deafened adolescents is sufficient to help these patients convert their mode of communication from visual to oral mode only. To verify this possibility we analyzed the performances of a group of late implanted pre-lingual deaf patients with different — cued speech [9] or sign language — modes of communication prior to cochlear implantation.

2. Materials and methods

Thirteen congenitally and profoundly deaf children, adolescents and young adults implanted in Geneva between the ages of 8 and 22 years (mean: 14 years) were included in the study. Nine patients were male and four female. They were implanted by the same surgeon using the same surgical technique, with fully implanted arrays. Surgery was uneventful in all cases. A Med-El implant was used in eight cases and a Clarion in five.

Several measurements were conducted on all children prior to implantation and after several years of cochlear implant use (mean 4.5 years): (i) audiometric hearing threshold at 250, 500, 1000, 2000 and 4000 Hz, (ii) *phoneme identification performance*, (iii) overall *auditory performance* and (iv) the *speech intelligibility* of spontaneous utterances. *Phoneme identification* performance was evaluated with a test developed in our laboratory [10]. This test evaluates vowel and consonant identification without visual or cognitive cues. Mean scores of identification were calculated as the mean of at least 168 vowel and 168 consonant presentations, gathered within two sessions.

Categories of *auditory performance* (CAP) [11] were used to classify patients in seven groups ranging from the lowest of not being aware of environmental sounds to the highest of being able to use the telephone with a familiar talker and to understand an unannounced subject without lip-reading (see Table 1). The *speech intelligibility* rating (SIR) [12] was used to classify patients in five levels ranging from the lowest of uttering only prerecognizable words in spoken language to the highest of having connected speech that is intelligible to all listeners, the child being understood easily in everyday contexts (see Table 2).

Table 1 Categories of auditory performance (CAP) [11].

Level 0	No awareness of environmental sounds
Level 1	Awareness of environmental sounds
Level 2	Responds to speech sounds
Level 3	Recognizes environmental sounds
Level 4	Discriminates at least two speech sounds without lip-reading
Level 5	Understands common phrases without lip-reading
Level 6	Understands conversation without lip-reading with a familiar talker
Level 7	Can use telephone with a familiar talker

Table 2 Speech intelligibility rating (SIR) [12].

Category 1	Prerecognizable words in spoken language (child's primary mode of everyday communication may be manual)
Category 2	Connected speech is unintelligible, intelligible speech is developing in single words when context and lip-reading cues are available
Category 3	Connected speech is intelligible to a listener who concentrates and lip-reads within a known context
Category 4	Connected speech is intelligible to a listener has little experience of a deaf person speech; the listener does not need to concentrate unduly
Category 5	Connected speech is intelligible to all listeners; the child is understood easily in everyday contexts

Finally, their dominant (e.g. everyday) mode of communication before and after implantation was documented via interviews with the patients and/or their families and classified into three categories: oral, cued speech [9] and sign language.

This study was done with the approval of the institution's review board and follows the rules of the Helsinki Convention.

3. Results

Before cochlear implantation, none of the patients used the oral language. None of the patients suffered from any handicaps besides deafness. Prior to implantation all patients received speech therapy. Six patients used cued speech and had followed education in normal schools with the support of cued speech. Seven patients used sign language and had followed education in sign language with incidental oral support and, in two cases, with some

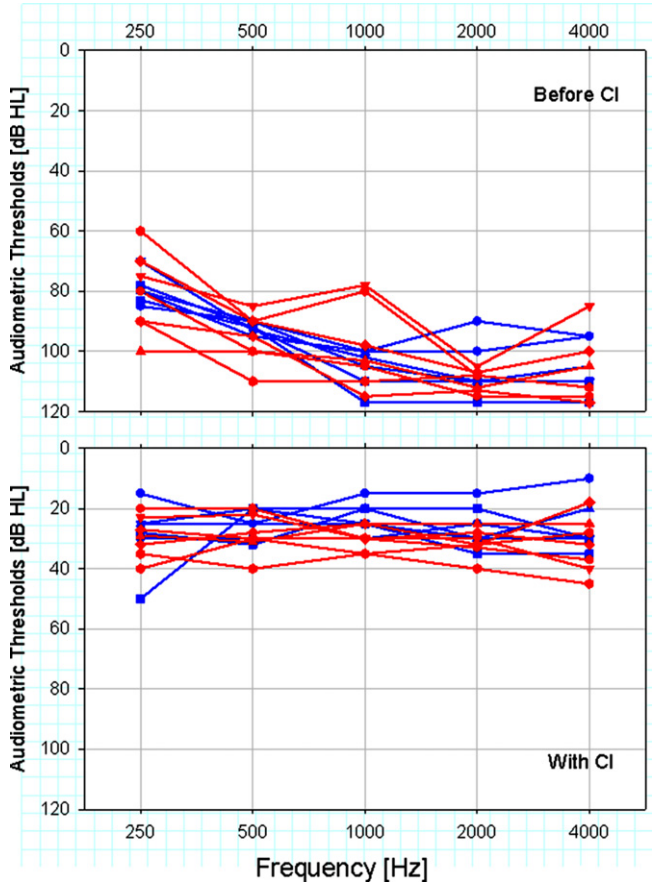

Fig. 1 Audiometric hearing thresholds of all 13 patients before and after cochlear implantation. Blue lines: users of the cued speech. Red lines: users of the sign language. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

cued speech. All had worn hearing aids. Their hearing thresholds ranged from 80 to 110 dBHL for frequencies above 250 Hz (Fig. 1). Their mean phoneme identification score was 21% (S.D. = 13%; ranging from chance level to 35% correct, Fig. 2). Using the CAP, 1 patient was categorized in level 2, 10 in level 3, and 2 in level 4 (Fig. 2). Using the SIR, five patients were rated level 1, four level 2, and four level 3 (Fig. 2).

After cochlear implantation, all hearing thresholds improved and were better than 40 dBHL (except for one single case at 250 Hz; Fig. 1). Their

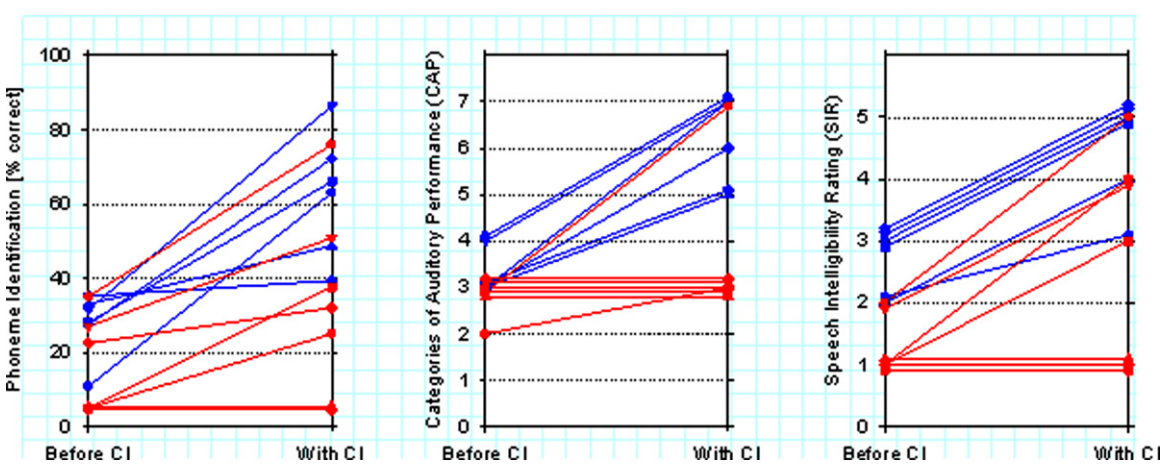

Fig. 2 Individual scores for phoneme identification, CAP and SIR before and after implantation. Blue lines: users of the cued speech. Red lines: users of the sign language. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

mean phoneme identification score improved from 21% to 47% corrects (S.D. 26; ranging from chance level to 86% correct, Fig. 2). Using the CAP, six patients reached level 3, two level 5, one level 6, and four level 7 (Fig. 2). Using the SIR, three patients were rated level 1, two level 3, three level 4 and five level 5 (Fig. 2). Basically, most of the patients benefited from cochlear implantation on all the measurements. At the time of the study patients had been using their implants from 3 to 8 years.

However, it is interesting to compare how the two groups of patients — those using cued speech and those using the sign language before implantation — improved their scores after implantation. Clearly, even though there is no significant difference in audiometric thresholds before and after implantation across the two groups the cued speech users reached significantly better phoneme identification ($p = 0.03$, $T = 2.34$) than their sign language pairs after implantation, while there was no significant difference across the two groups before implantation. Similarly, cued speech users obtained significantly better CAP scores ($p = 0.004$, $T = 3.59$) than their sign language pairs after implantation, while there was no significant difference across the two groups before implantation. For SIR scores, both groups obtained significantly different scores, but the difference was statistically significant before implantation ($p = 0.0004$, $T = 4.95$) and remained significant after implantation ($p = 0.04$, $T = 2.32$).

Finally, there was also marked differences between the two groups in the dominant mode of communication patients used after implantation: four out of six cued speech users converted to exclusive use of the oral language, while only one out of seven former users of the sign language converted to the use of the oral language in everyday situations.

4. Discussion

The benefit of CI in pre-lingually deaf children implanted early in life, preferably before the age of 3 years is now well established [1—5,13,14] as it is in post-lingually deaf patients [15,16]. The question of how useful is cochlear implantation after the age of 8 years in pre-lingually deaf patients is still debated. In our series, the hearing thresholds after cochlear implantation improved to reach similar level in all patients, suggesting that the cochlear implant brought a roughly similar perception of sounds to all of them. Improvements in phoneme identification, auditory performance and speech intelligibility were also observed in most patients, but former cued speech users benefited more than former language sign users.

The explanation most commonly accepted for this observation is that sign language users having had no sound stimulation during the critical period of auditory plasticity [17,18] develop visual instead of oral communication skills, leading to an irreversible visual colonization of the auditory cortex [19]. This hypothesis is supported by experimental studies showing that the destruction of the cochlea during the early phase of development in young animals elicits the establishment of new innervating patterns in the auditory pathway [20,21] and the organization of a new tonotopic distribution in the cerebral cortex [22,23].

Based on the present results, we argue that the reason for the bad results of late implantation in sign language users is not the lack of auditory stimulation but the ignorance of the acoustic (and temporal) structure of the oral language. If not, why would cued speech users obtain better benefits from cochlear implants than sign language users? Strategies involving learning the oral language with the help of cued speech [9] or lip-reading [24] can help to neutralize the consequences of the lack of auditory stimulation during the critical period of language acquisition. Oral language is a sound code in which each phoneme follows the other to form words, which are in turn arranged in a grammatical order to form sentences. Even without hearing, the patients who learnt to communicate using the cued speech code are acquainted with this structure [9]. They also develop a "listening attitude" with the help of the hearing aid to detect any useful speech information from incoming sound. Later, if they receive a cochlear implant they can coherently integrate the sounds they perceive. The sign language users, who function in a visual (and spatial) communication mode, receive information via the overall sequence of "pictures" created by the interlocutor. They do not learn to integrate the chain of sounds of speech. In addition, even though they might wear hearing aids they do not develop a "listening attitude". It is difficult to convert from a visual (and spatial) to an auditory (and temporal) communication system [25—27]. However, this is not impossible, as we report here one of such exceptional cases, a former exclusive sign language user, who became able to convert to the oral mode only.

This small group of patients confirms that a prelingual or congenital deaf can convert from a visual to an oral mode of communication after a delayed implantation. The previous knowledge of the structure of the oral language as promoted by the use of the cued speech code influences very positively the outcome in late implanted subjects. The adoption of oral communication with the cued speech code should therefore be considered in cases where

delayed cochlear implantation can be envisioned. This being said, an elder and motivated pre-lingual or congenital deaf who is aware of the difficulties of the task to undertake can still be exceptionally considered as candidate for cochlear implantation.

References

[1] A. Snik, M. Makhdoum, A. Vermeulen, J. Brokx, P. van den Broek, The relation between age at the time of cochlear implantation and long-term speech perception abilities in congenitally deaf subjects, Int J Pediatr Otorhinolaryngol 44 (1997) 121—131.

[2] P. Kileny, Zwolan, C. Ashbaugh, The influence of age at implantation on performance with a cochlear implant in children, Otol Neurotol 22 (2001) 42—46.

[3] J. Wu, H. Yang, Speech perception of Mandarin Chinese speaking young children after cochlear implant use: effect of age at implantation, Int J Pediatr Otorhinolaryngol 67 (2003) 247—253.

[4] T. Nikolopoulos, G. O'Donoghue, S. Archbold, Age at implantation: its importance in pediatric cochlear implantation, Laryngoscope 109 (1999) 595—599.

[5] R. Harrison, J. Panesar, H. El-Hakim, M. Abdolell, R. Mount, B. Papsin, The effects of age of cochlear implantation on speech perception outcomes in perlingually deaf children, Scand Audiol Suppl 53 (2001) 73—78.

[6] J. Sarantz, R. Cowan, P. Blamey, K. Galvin, G. Clark, Cochlear implants for congenitally deaf adolescents. Is open-set speech perception a realistic expectation? Ear Hear 15 (1994) 400—403.

[7] D. Schramm, E. Fitzpatrick, C. Seguin, Cochlear implantation for adolescents and adults with prelinguistic deafness, Otol Neurotol 23 (2002) 698—703.

[8] E. Yucel, G. Sennaroglu, Is psychological status a determinant of speech perception outcomes in highly selected good adolescent cochlear implant users? Int J Pediatr Otorhinolaryngol 71 (2007) 1415—1422.

[9] R.O. Cornett, Cued speech, manual complement to lipreading, for visual reception of spoken language. Principles, practice and prospects for automation, Acta Otorhinolaryngol Belg 42 (1988) 375—384.

[10] M. Pelizzone, C. Boex, P. Montandon, Vowel and consonant identification tests can be used to compare performances in a multilingual group of cochlear implant patients, ORL J Otorhinolaryngol Relat Spec 55 (1993) 341—346.

[11] S. Archbold, M.E. Lutman, T. Nikolopoulos, Categories of auditory performance: inter-user reliability, Br J Audiol 32 (1998) 7—12.

[12] C. Allen, T. Nikolopoulos, D. Dyar, G. O'Donoghue, Reliability of a rating scale for measuring speech intelligibility after pediatric cochlear implantation, Otol Neurotol 22 (2001) 631—633.

[13] M. Manrique, F. Cervera-paz, A. Huarte, M. Molina, Prospective long-term auditory results of cochlear implantation in prelinguistically deafened children: the importance of early implantation, Acta Otolaryngol Suppl 552 (2004) 55—63.

[14] D. Kaplan, D. Shipp, J. Chen, A. Ng, J. Nedzelski, Early-deafened adult cochlear implant users: assessment of outcomes, J Otolaryngol 32 (2003) 245—249.

[15] O. Sterkers, I. Mosnier, E. Ambert-dahan, E. Herelle-Dupuy, A. Bozorg-Grayeli, D. Bouccara, Cochlear implants in elderly people: preliminary results, Acta Otolaryngol 552 (2004) 64—67.

[16] D.W. Proops, I. Donaldson, H.R. Cooper, J. Thomas, S.P. Burrell, R.L. Stoddart, et al., Outcomes from adult implantation, the first 100 patients, J Laryngol Otol 24 (1999) 5—13.

[17] J. Moore, Maturation of human auditory cortex: implications for speech perception, Ann Otol Rhinol Laryngol 111 (2002) 7—10.

[18] R. Harrison, K. Gordon, R. Mount, Is there a critical period for cochlear implantation in congenitally deaf children? Analyses of hearing and speech perception performance after implantation, Dev Psychobiol 46 (2005) 252—261.

[19] S. Teoh, D. Pisoni, R. Miyamoto, Cochlear implantation in adults with prelingual deafness. Part II. Underlying constraints that affect audiological outcomes, Laryngoscope 114 (2004) 1714—1719.

[20] A. Kral, J. Tillein, S. Heid, R. Klinke, R. Hartmann, Cochlear implants: cortical plasticity in congenital deprivation, Prog Brain Res 157 (2006) 283—313.

[21] B. Clopton, M. Silverman, Plasticity of binaural interaction: II. Critical period and changes in midline response, J Neurophysiol 40 (1977) 1275—1280.

[22] J. Guiraud, J. Besle, L. Arnold, P. Boyle, M. Giard, O. Bertrand, et al., Evidence of reorganization of the auditory cortex in cochlear implant users, J Neurosci 27 (2007) 7838—7846.

[23] A. Sharma, P. Gilley, M. Dorman, R. Baldwin, Deprivation-induced cortical reorganization in children with cochlear implants, Int J Audiol 46 (2007) 494—499.

[24] S. Moody-Antonio, S. Takayanagi, A. Masuda, E.T. Auer, L. Fisher, L. Bernstein, Improved speech perception in adult congenitally deafened cochlear implant recipients, Otol Neurotol 26 (2005) 649—654.

[25] S. Torres, I. Moreno-Torres, R. Santana, Quantitative and qualitative evaluation of linguistic input support to a prelingually deaf child with cued speech: a case study, J Deaf Stud Deaf Educ 11 (2006) 438—448.

[26] E. Cassandro, M. Nicastri, G. Chiarella, E. Genovese, L. Gallo, M. Catalano, Development of communication and speech skills after cochlear implant in a sign language child, Acta Otorhinolaryngol Ital 23 (2003) 88—93.

[27] C.M. Connor, Examining the communication skills of a young cochlear implant pioneer, J Deaf Stud Deaf Educ 11 (2006) 449—460.