Cochlear Implants International
Cochlear Implants Int. **10**(1), 19–24, 2009
Published online 20 October 2008 in Wiley InterScience
(www.interscience.wiley.com) **DOI**: 10.1002/cii.373

What to do with the other ear after cochlear implantation*

RA TANGE, W GROLMAN, WA DRESCHLER, Department of Otorhinolaryngology, Academical Medical Centre, University of Amsterdam, Amsterdam, The Netherlands

ABSTRACT *Unilateral cochlear implantation has become a widely accepted surgical intervention for both deaf children and adults. It is a reliable and effective method to rehabilitate profound deafness. Recently the benefits of the use of a contralateral hearing aid (bimodal stimulation) with a cochlear implant became clear. Bilateral cochlear implantation benefits bilateral input into the auditory system for adults and children. To provide the binaural advantages experienced by normal hearing subjects bilateral cochlear implantation or bimodal stimulation is probably indicated. Whether to choose between both possibilities depends on many factors. Cortical auditory evoked potential (CAEP) measurements can be an important tool to decide bilateral implantation in young children. Enough residual hearing in the non-implanted ear might benefit from bimodal stimulation. New protocols are needed for the audiological management for recipients of cochlear implants. Copyright © 2008 John Wiley & Sons, Ltd.*

Keywords: Cochlear implant; Bilateral implantation; adult; child

Introduction

Surgical rehabilitation by cochlear implantation has become more or less a routine procedure in cases of severe deafness in which conventional rehabilitation with acoustic stimulation is not helpful anymore. However, in contrast with rehabilitation with acoustic hearing aids, unilateral rehabilitation remains the standard in cochlear implantation. This paper focuses on the opportunities to profit as far as possible from bilateral stimulation.

Binaural hearing is important to better understand speech in silence, but especially in noisy environments. Furthermore, benefits such as sound localisation,

*Presented at the III Meeting Consensus on Auditory Implants 14–16 June 2007, Marseille, France.

more natural hearing and reduced listening effort have shown to be important advantages of bilateral hearing aids (Boymans and Dreschler, 2007). It is worthwhile to investigate the options to improve the quality of hearing and therefore the quality of life of severely deaf patients implanted with one cochlear implant (Ching et al., 2006). Bilateral input into the auditory system can also be important for them, both for adults (Ramsden et al., 2005; Ricketts et al., 2006; Schleich et al., 2004) and for children (Ching et al., 2001, 2006; Kuhn-Inacker et al., 2004; Litovski et al., 2006a, 2006b). Interaural cooperation of the central auditory pathways from the auditory nerve to the cortex is important for sound localisation and for speech understanding in complex listening situations. The choice for cochlear-implanted patients is between bimodal stimulation and bilateral cochlear implantation (Offeciers et al., 2005).

Bimodal stimulation

The use of a conventional hearing aid in the non-implanted ear (bimodal stimulation) with some residual hearing is more or less a standard procedure in cochlear implant rehabilitation protocols at present. Bimodal stimulation is used in patients who have residual hearing and good performance with the hearing aid in the non-implanted ear. Bimodal stimulation offers the advantage of stimulation of the non-implanted ear such as better speech discrimination in quiet and noise and in sound localisation (Ching et al., 2001, 2006; Kuhn-Inacker et al., 2004; Litovski et al., 2006a, 2006b; Ramsden et al., 2005; Ricketts et al., 2006; Schleich et al., 2004). The main advantages are that there is no need for a second operation (as in bilateral implantation) and it is cost-effective. Disadvantages of bimodal stimulation can be a reduction in the performance achieved with the cochlear implant alone. Bimodal stimulation is recommended in cases of residual hearing and good hearing aid performance in the non-implanted ear. It is difficult in young children to determine the hearing ability of the non-implanted ear. So bimodal stimulation is recommended as well in these cases.

Bilateral cochlear implantation

Bilateral cochlear implantation furnishes greater benefit in binaural function and hearing comfort, especially in children. In adults the gain from bilateral cochlear implantation depends on the moment of deafness (pre- or post lingual) (Ching et al., 2006; Schleich et al., 2004).

Both ears can be implanted in a one-stage or a two-stage surgical procedure. A one-stage technique is preferable because of cost-effectiveness. In prelingually deaf children the interval between the two cochlear implantations should be short (Manrique et al., 2004) because this makes additional training and rehabilitation less important and will avoid the possible refusal of the second implant. Bilateral implantation allows bilateral cortical stimulation and restoration of binaural hearing.

DOI: 10.1002/cii

An obvious, but nevertheless important, advantage of bilateral stimulation is that we are sure that the better ear will be stimulated electrically. Additionally, an important advantage of bilateral implantation in young children is the positive effect on the development of the central auditory system during the period of neural plasticity and language acquisition. Disadvantages of bilateral implantation are the costs of the procedure and the fact that possible new techniques in the future will be impossible after cochlear implantation. Bilateral implantation is recommended in meningitis cases with ossification of the cochlea, Usher's syndrome, far-advanced cochlear otosclerosis and in children with profound deafness who are in their speech and language acquisition period of life (Offeciers et al., 2005).

Bilateral stimulation by hearing aid or second cochlear implant is important for optimal development of the auditory pathways in cochlear deafness. In neurobiology it is well known that stimulation must be delivered to the developing sensory system within a sensitive period, in order for that system to develop normally (Manrique et al., 2004; Sharma et al., 2002a, 2005, 2006). The sensitive period for the development of the central auditory pathways in humans is up to about 3.5 years of age (Sharma et al., 2006).

Objective measures for candidacy in young children

Given the large uncertainties in the diagnosis of auditory performance in young children, an objective measure for candidacy is wanted. Because speech tests in young children with severe sensorineural hearing loss or deafness are impossible cortical auditory evoked potential (CAEP) measurements can be helpful in the selection process for cochlear implants and in the follow-up, monitoring the effects on the development of the central auditory system (Kelly et al., 2005; Purdey and Kelly, 2001). P1 latency potentials measured by CAEP in deaf children are different from the potentials found in normal hearing. These differences in responses reduce after a period of rehabilitation by hearing aids or cochlear implants. If (bilateral) stimulation is delivered within the sensitive period for the development of the central auditory pathways CAEP latencies can reach age-normal values within three to six months of stimulation (Sharma et al., 2002b, 2006).

Decision trees for cochlear implantation candidacy

Figure 1 shows the decision tree for adults, used in our centre to choose unilateral electric stimulation, bimodal stimulation or bilateral electric stimulation. For bilateral stimulation a useable degree of residual hearing loss should be present and the results with hearing aids should complement the results with (unilateral) electric stimulation, either in terms of speech intelligibility or horizontal localisation. If binaural benefits are absent from bimodal stimulation, one can consider bilateral electric stimulation, especially in cases of post-meningitis, Usher's syndrome, or advanced cochlear otosclerosis (at the non-implanted ear). The importance of

DOI: 10.1002/cii

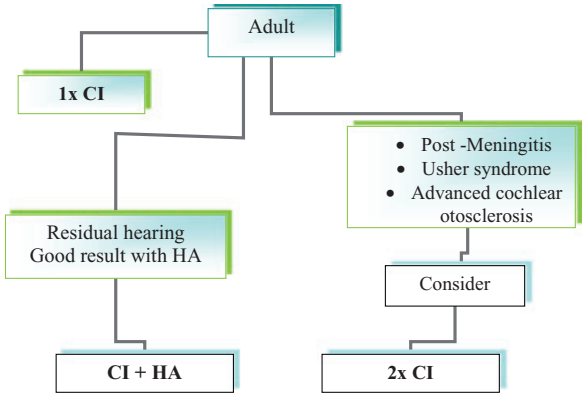

Figure 1: Decision tree bimodal stimulation or bilateral cochlear implantation in adults. CI = Cochlear implantation; HA = hearing aid.

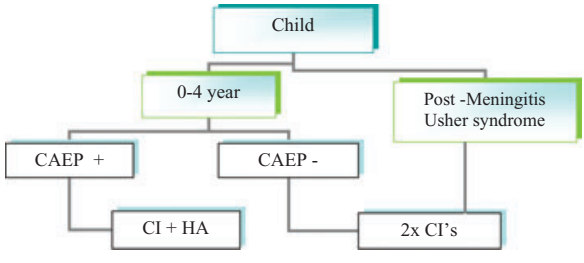

Figure 2: Decision tree bimodal stimulation or bilateral cochlear implantation in children. CAEP = Cortical auditory evoked potential; CI = cochlear implantation; HA = hearing aid.s

CAEP in adults is still not well studied enough to play a role in decision making for hearing rehabilitation.

Figure 2 shows the decision tree for young deaf children (birth to four years of age). In cases of post-meningitis and/or Usher's syndrome, we advocate direct application of two cochlear implants. For other children, the choice between bimodal and bilateral electric stimulation should be based on the results of CAEP recordings. If CAEP recordings show that the central auditory pathways are developing well with bimodal stimulation, there is no strong need for bilateral cochlear implants.

Bilateral cochlear implantation (preferable simultaneously one-stage technique) is advisable in children younger than four years with no CAEP response with optimally fitted hearing aids.

Our data on the other ear after cochlear implantation

Of our first 107 cases, 55 implanted patients (all adults, average age 56.1) use their cochlear implant without hearing aid support in the other ear. Forty six patients

DOI: 10.1002/cii

(average age 46.2) make use of bimodal stimulation. Forty one subjects use an electroacoustical hearing instrument and five of them use a body hearing instrument in the non-implanted ear. Eleven patients have bilateral cochlear implants. Three received their second implant by the two-stage surgical technique; all others were implanted during a single surgical procedure. All our bilateral cochlear implant cases were children (average age 3.8) except for one adult female patient (23 years old).

In conclusion, in 50 per cent of our cases unilateral implantation was performed without binaural stimulation. These patients were all older than 50 years. In 40 per cent of cases bimodal stimulation was provided by hearing aid. In ten per cent of cases bilateral cochlear implantation was performed in young children. One third of all our implanted children received bilateral cochlear implantation.

Conclusions

There is growing experimental evidence that binaural stimulation in severely hearing impaired or deaf subjects is of great importance to achieve the best results of auditory rehabilitation. Studies with bimodal and bilateral electric stimulation show that binaural processing is feasible and successful, but that there are not yet strict criteria as to which approach is most successful in individual patients. This paper shows that a well-structured approach is helpful in the selection process, and that CAEP measurements may provide essential additional information for the candidacy of young children.

References

Boymans M, Dreschler WA (2007) Evidence for benefits of bilateral hearing aids. In Hearing Care for Adults, 13–15th November 2006, Chicago, USA, chapter 24: 287–298.

Ching TC, Incerti P, Hill M, van Wanrooy E (2006) An overview of binaural advantages for children and adults who use binaural/bimodal hearing devices. Audiology and Neurotology 11(suppl 1): 6–11.

Ching TY, Psarros C, Hill M, Dillon H, Incerti P (2001) Should children who use cochlear implants wear hearing aids in the opposite ear? Ear and Hearing Oct; 22(5): 365–380.

Ching TYC, van Wanrooy E, Hill M, Incerti P (2006) Performance in children with hearing aids or cochlear implants: Bilateral stimulation and binaural hearing, International Journal of Audiology 45(Supplement1):S108–S112.

Kelly A, Purdey SC, Thorne PR (2005) Electrophysiological and speech perception measures of auditory processing in experienced adult cochlear implant users. Clinical Neurophysiology 116: 1235–1246.

Kühn-Inacker H, Shehata-Diel W, Müller J, Helms J (2004) Bilateral cochlear implants: a way to optimize auditory perception abilities in deaf children? International Journal of Pediatric Otorhinolarygology 86: 1257–1266.

Litovski RY, Johnstone PM, Godar S, Argawal S, Parkinson A, Peters R, Lake J (2006a) Bilateral cochlear implants in children: Localization acuity measured with minimum audible angle, Ear & Hearing 27: 43–59.

Litovski RY, Johnstone PM, Godar SP (2006b) Benefits of bilateral cochlear implants and/or hearing aids in children. International Journal of Audiology Jul; 45(Suppl): 78–91.

DOI: 10.1002/cii

Manrique M, Cervera-Paz FJ, Huarte A (2004) Advantages of cochlear implantation in prelinguaal deaf children before 2 years of age when compared with later implantation, Laryngoscope 114: 1462–1469.

Offeciers E, Morera C, Müller J, Huarte A, Shallop J, Cavallé L (2005) International consensus on bilateral cochlear implants and bimodal stimulation. Acta Oto-Laryngologica 125: 918–919.

Purdey SC, Kelly A (2001) Cortical auditory potential testing in infants and young children. New Zealand Audiol Soc Bulletin 3(11):16–24

Ramsden R, Greenham P, O'Driscoll M, Mawman D, Proops D, Craddock L, Fielden C, Graham J, Meerton L, Verschuur C, Toner J, McAnallen C, Osborne J, Doran M, Gray R, Pickerill M (2005) Evaluation of bilaterally implanted adult subjects with the Nucleus 24 cochlear implant system. Otology and Neurotology 26: 988–998.

Ricketts TA, Grantham W, Ashmead DH, Haynes DS, Labadie RF (2006) Speech recognition for unilateral and bilateral cochlear implant modes in the presence of uncorrelated noise sources. Ear & Hearing 27: 763–773.

Schleich P, Nopp P, D'Haese P (2004) Head shadow, squelch and summation effects in bilateral users of the MedEl combi 40/40+ cochlear implant. Ear & Hearing 25: 197–204.

Sharma A, Dorman MF (2006) Central auditory development in children with cochlear implants: clinical implications. Adv Otorhinolaryngol 64: 66–88.

Sharma A, Dorman MF, Spahr AJ (2002a) A sensitive period for the development of the central auditory system in children with cochlear implants: Implications of age of implantation, Ear & Hearing 6(23): 532–539.

Sharma A, Dorman M, Spahr A, Wendell Todd N (2002b) Early Cochlear implantation in children allows normal development of central auditory pathways. Annals of Otology, Rhinology & Laryngology 111: 38–41.

Sharma A, Dorman MF, Kral A (2005) The influence of a sensitive period on central auditory development in children with unilateral and bilateral cochlear implants, Hearing Research 203: 134–143.

Address correspondence to: RA Tange, Dept of Otorhinolaryngology, Academical Medical Centre, University of Amsterdam, Meibergdreef 9, 110 DD, Amsterdam, The Netherlands. Tel: +31 20 5663486. Email: R.A.Tange@ear-surgeon.com

DOI: 10.1002/cii