Cochlear Implants

D J Wagenfeld, Amu Müller

(CME, September 2000, Vol 18, No 9, 756-761)

Beneficial outcomes of cochlear implantation depend on correct selection of candidates.

Cochlear implants are firmly established as an effective option in the rehabilitation of adults and children with severe and profound hearing impairment.

A cochlear implant is a hearing prosthesis designed to provide auditory sensation to adults and children who derive little or no benefit from hearing aids. The hearing sensation from the implant is provided through electrical stimulation of the auditory nerve via electrodes implanted in the cochlea. The electrical stimulation bypasses the damaged parts of the cochlea to directly stimulate the hearing nerves.

A cochlear implant consists of internal and external components (Figs 1 and 2):

➤ The internal components include the electrodes that are implanted in the cochlea which is attached to a receiver/stimulator and an internal magnet.

➤ The external parts consist of a speech processor, microphone, cables and transmitting coil with an external magnet.

Sound is received by the microphone and sent to the speech processor where it is analysed and digitised according to a specific speech coding strategy. These coded signals are then sent to the external transmitting coil thatsends the code across the skin to the internal implant. The coded signal contains information as to which electrodes to stimulate and the intensity level required to generate the appropriate sound sensations. The electrodes stimulate the nerve fibres via a controlled electrical current which is eventually recognised as sound by the brani. Fig. 3 illustrates the various steps in this process.

More than 28.000 children and adulots worldwide have received a cochlear implant. In order to determine suitability for a cochlear implant a number of selection criteria need to be fulfilled and this necessitates assessment by a multidisciplinary team. The team consists of physicians, audiologists, speech-language pathologists, educators, psychologists and social workers.

Selection Criteria

The criteria used to determine candidacy for a cochlear implant have changed since cochlear implants were first introduced in the early 1980s. These changes include implanting:

- ➤ persons with increasing levels of residual hearing
- ➤ children under the age of 2 years
- ➤ more patients with abnormal cochleas
- ➤ patients with additional handicaps.

Selection criteria are based on the following critical issues: degree of hearing impairment, age at implantation, duration of deafness, postoperative rehabilitation and educational facilities, motivation and commitment of patients, parents and family members.

Selection criteria for children

Degree of hearing loss

Children who have a bilateral profound sensorineural hearing loss demonstrate little or no benefit from appropriate binaural hearing aids. Little or no benefit from hearing aids is defined as a lack of progress in the development of auditory, speech and language skills after intensive rehabilitation over a period of 6 months.

Children with bilateral severe hearing impairment who derive minor benefit from hearing aids can be considered as candidates. In the case of children under 2 years of age with limited speech-language development where speech perception scores cannot be obtained, aided thresholds of 60 dB HL across the speech frequencies can serve as a guideline to determine candidacy.

Duration of deafness and age at implantation

Congenital/prelingual deafness

A child with a congenital bilateral severe-to-profound sensorineural hearing impairment should preferably be implanted within the first 2 years of life and at least before the age of 4 years. Congenitally deaf children who receive implants when they are 2-4 years old obtain higher speech perception scores than children who receive implants when they are 4-9 years of age.

Adolescents

The prognosis for benefit from cochlear implants in congenitally deaf adolescents has been poor. However, published research suggests that prospective adolescent patients should be considered on an individual basis. Factors in determining candidacy are early auditory experience,

consistent hearing aid use and verbal communication as the mode of communication.

Postlingual hearing impairment

If the hearing impairment occurs after the age of 6 years, when the auditory and speech-language systems are more or less fully developed, cochlear implantation should be performed as soon as possible. This will reactivate the auditory neurons and prevent degeneration.

The educational setting

A cochlear implant can only be justified if appropriate education rehabilitation follows surgery. The child's family and education system will be the determining factors in the use of the new auditory information provided by the cochlear implant. Children who are enrolled in programmes where spoken language is used as the mode of communication tend to achieve higher speech perception scores than children in total communication programmes. A commited programme designed to use and develop the child's auditory abilities is required. A child in a signing language programme would not be considered a suitable cochlear implant candidate.

Parental involvement

Research and clinical observations have found that children whose progress was most favourable were children of parents who were most involved in their child's education.

Selection criteria for adults

In the case of adults the device is intended for use in individuals 18 years and older who have a bilateral, postlingual, sensorineural hearing impairment and who obtain limited benefit from appropriate binaural hearing aids. These individuals typically have a moderate or profound hearing loss in the low frequencies and a profound hearing loss (> 90 dB HL) in the mid-to-high speech frequencies. Limited benefit from amplification is defined as speech perception test scores on sentences of ≤ 40% in the best-aided listening conditions without lip reading.

Pre-lingually and peri-lingually deafened adults should only be considered for implantation if they are using spoken language as their mode of communication, have used hearing aids all their lives and are highly motivated to integrate the new auditory information provided by the implant into their daily lives. Congenitally deafened adults with no auditory experience are not suitable candidates.

Special considerations for disadvantaged patients

No highly technical device should be implanted in a patient until a lifetime commitment, not only to the maintenance of the device, but also to the sociological and educational implications, can be given. We have included additional criteria for disadvantaged patients in South Africa:

➤ Adults must have the skill to enable re-entry to the workplace and must be motivated to be fainfully employed.

➤ Children must have adequate family support, parents must be gainfully employed, and accessible, compulsory, appropriate educational and audiological facilities must be available.

The following criteria may eliminate a child or adult as a potential cochlear implant candidate:

➤ lack of eighth nerve integrity bilaterally

➤ neurological damage that would prevent the processing of auditory information

➤ autism.

Preoperative Assessment and Evaluation

The primary purpose of the preoperative evaluation is to determine whether the patient is medically, audiologically and psychologically suitable for a cochlear implant.

ENT and medical evaluation

A complete medical and ENT evaluation is vital, to attempt to identify the aetiology of the hearing loss, and to determine whether there are other medical factors which may influence the patient's suitability for surgery and rehabilitation.

Cochlear imaging

Computerised tomography (CT) of the cochlea not only allows the ENT surgeon to assess the structure and patency of the cochlea but also provides information regarding the structures to be encountered in the surgical approach to the cochlea. It is also possible to visualise neo-ossification of the cochlea following meningitis as well as congenital abnormalities.

Magnetic resonance imaging (MRI) is particularly useful for assessing the patency of the cochlea. It may show evidence of fibrosis preceding neo-ossification, and demonstrate neural structures such as the integrity of the cochlear nerve and its central connections. Imaging thus assists in corroborating the feasibility of the procedure, and is useful in selecting the appropriate ear for implantation.

Audiological evaluation

The primary purpose of the preoperative audiological evaluation is to determine the type and severity of the hearing loss. It is important to ensure that appropriate hearing aids have been fitted and that lack of benefit is not a result of poorly fitted hearing aids. The development of speech perceptual skills can be influenced greatly by the length of time that the candidate has used appropriate amplification.

Speech and language evaluation

The purpose of this is to assess the child's communication skills with respect to normative data regarding language development, and to determine whether the child demonstrates additional developmental speech and language disorders. Children with cochlear implants should undergo regular scheduled speech and language evaluations. The results are used to determine auditory and language training goals, to monitor progress and to alert the clinician to the possibility of other developmental, neurological, or cognitive problems.

Psychological evaluation

Psychological evaluation is particularly important in the paediatric population. The child's cognitive abilities are evaluated to rule out factors other than hearing impairment which may interfere with auditory development.

Surgery

The surgery varies according to the nature of the particular device being implanted. The electrode array is introduced into the scala tympani, either through the round window membrane or via a separate cochleostomy anterior and inferior to it. The receiver/stimulator is fixed to the skull postero-superiorly to the pinna under the pericranium. The skin incision that is used is a vertically extended postauricular incision that lies anterior to all the implanted hardware and requires no mobilisation of flaps. The possibility of ischaemic flap problems developing is thus excluded. No drains are needed, and the patients spend a maximum of 24 hours in hospital. The implant was designed to allow implantation in a 6-month-old infant, and the surgical techniques used in infants and children do not differ in principle from those used in adults. There are minor adaptations to accommodate age-related aspects of head growth, thickness of skull, and also the tendency to otitis media.

Device Programming

Activation of the device begins approximately 3-4 weeks after surgery. Two psychophysical measures are obtained in order to create a programme for the speech processor: electrical thresholds and comfort levels. Electrical thresholds are the softest sounds that can be identified by the patient. Electrical comfort levels are defined as the loudest sounds that can be listened to comfortably for a sustained period of time. These two measures are obtained for each electrode and are combined to create a MAP, or programme, to be stored on the speech processor. These threshold and comfortable levels determine the boundaries for electrical stimulation according to the specific speech coding strategy that is used by the patient.

The threshold and comfortable levels are obtained through conditioned responses or observation of behavioural responses in very young children. If a child cannot reliably indicate the presence or loudness of the sound, objective measures such as the electrical stapedius reflex thresholds and neural response telemetry can be used. These measures enable the audiologist to

predict audible and safe levels of electrical stimulation. Follow-up programming is scheduled at different intervals.

Outcomes

Factors that appear to influence the benefit received are: length of deafness, number of surviving neurons, motivation, educational environment, and commitment of patients and their family members.

Children

Cochlear implantation has provided deaf children with a means of access to auditory information that is essential for language development. Children with cochlear implants exhibit better speech perception and speech production skills in terms of intelligibility and the number of vowels and consonants they produce compared with severe-to-profoundly deaf children who use hearing aids.

Children with cochlear implants exceed the rate of development, and do not seem to reach a plateau in their performance, in comparison with children who use hearing aids. Implanted children may learn language at the same rate as hearing children, even though some may retain an overall language delay. Children who receive implants before the age of 5 years have a greater chance of being placed in mainstream schools than children who receive implants after the age of 5 years. Early implantation, accompanied by aural (re)habilitation, contributes to the growth of language skills that lead to the increased rate of placement in mainstram schools.

Adults

Most post-lingually deafened adults typically notice a benefit immediately after the activation of the electrodes and many of them can understand speech without lip-reading on the first day of the activation of the electrodes. Their performance improves over time. Approximately half of the population of adulot patients fitted with the current generation of cochlear implants achieve scores of 80-100% on sentence recognition tests when the sentences are presented without visual cues. This outcome means that more than half of the implantees can work in an environment that requires the use of a telephone. Implant recipients who can understand speech without lip-reading can perform the activities of daily living more effectively. Conversing with others becomes less stressful. The psychological and social effects of implantation for adults are generally positive. This is expressed as a decline in loneliness, depression and social isolation and an increae in self-esteem, independence, social integration, and vocational prospects. Listening in noisy environments, however, remains difficult for implant patients. Pre-lingually deafened adults generally show little improvement in speech perception scores after cochlear implantation, although many may derive benefit from hearing some aspects of the speech and environmental signals and continue to use the device.

In a Nutshell

Cochlear implantation is a cost-effective treatment in the restoration of hearing in severely and profoundly deaf children and adults.

There is strong evidence that prelingually deaf children should receive implants as early as possible in order to facilitate the development of speech perception and improved speech intelligibility.

Children deafened through meningitis should be referred as soon as possible after meningitis has occurred to avoid the surgical complications associated with ossification of the cochlea.

Paediatric cochlear implantation, accompanied by aural (re)habilitation, leads to higher rates of placement in mainstream school and lower dependence on special educational support services. This cost saving indicates the educational cost benefit of cochlear implant (re)habilitation for many children.

Cochlear implantation improves the comunication ability in most adults with severe-to-profound hearing impairment and leads to positive psychological and social benefits.