MULTIPLE-CHANNEL COCHLEAR IMPLANTS FOR CHILDREN: THE MELBOURNE PROGRAM


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Although there have been 300 years of deaf education, profoundly-totally deaf children today on average are not able to reach the same level of achievement as their normally hearing peers (Geers & Moog, 1989). This failure of deaf children to develop their true potential is largely due to the difficulty they have in communicating with normally hearing people. During the last 300 years there have been basically two different methods of education used (The New Encyclopaedia Britannica, 1983). Firstly, one which maximises auditory and lip reading cues (auditory/oral), advocated by Juan Pablo Bonet (1620), and one which uses a series of signs to convey meaning (signing), developed by Charles-Michel (1712-89). In addition, there is a method which endeavours to combine both auditory/oral and signing approaches called total communication. In practice, however, children taught by total communication tend to receive speech more predominantly by one or other of these methods.

Within the two main methods are variations. For example, with the auditory/oral system some educators prefer to teach by combining auditory information with lip reading cues while others endeavour to get children to develop their listening skills by withholding visual information (the auditory/verbal method). A further variation of the auditory/oral method is to use cueing supplements. In this situation the child is helped by providing additional visual cues when speech sounds look the same on the lips. There are also different approaches to training with the auditory/oral schemes. On the one hand, educators may emphasize training in listening to segments of speech and speaking in very structured situations. On the other hand, they may emphasize learning conversational speech in more natural and unstructured ways similar to that which would occur with normally hearing children.

In the case of signing there are basically two different systems: children may be taught signed English, or, they may be taught the Australian version of sign language of the deaf (Auslan). In the case of signed English, the signs represent individual words as well as conveying grammatical information such as tense. This form of signing is used in total communication, and although it is difficult for children to attend to the speech signal by the auditory/oral mode at the same time as signed English, they can develop the skills to communicate by either one used separately. In the case of the sign language of the deaf, the grammatical structure is quite different from the structure of English. In practice, this method makes it difficult to learn written language, and is not appropriate for combining with an auditory/oral method of education.

As the multiple-channel cochlear implant provides information by stimulating hearing sensations, it is optimally used by combing these auditory signals with lip reading cues. Consequently, children receiving a cochlear implant should ideally be educated using an auditory/oral method.

Management Team

In managing a child for a cochlear implant we consider that a team approach is essential. The management team is outlined in Figure 1. The team consists of otologists, audiologists, speech pathologists, educators of the deaf, and consultants in psychology, child psychiatry and social work.

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work. The team also requires a leader who is conversant with most aspects of the program. Furthermore, there is a need for very good liaison between members of the team based in a hospital and the teachers in the school. The team is responsible for the following areas in a cochlear implant child's management: preoperative evaluation and selection; parent counselling; surgery; auditory training in speech production, language and auditory perception and audiological assessment. These responsibilities are listed in Figure 2.

![Management team — responsibilities: cochlear implants for children.](image)

**Preoperative Evaluation and Selection**

The preoperative evaluation and selection process takes place in five stages. At any stage a child may be considered unsuitable for an implant, and may be referred for an alternative sensory aid. The stages are shown in Figure 3.

![Preoperative evaluation and selection: cochlear implants for children.](image)

The first stage consists of an initial medical assessment, audiometric testing of hearing thresholds, and general counselling to ensure that the parents' expectations are realistic.

The second stage consists of a detailed clinical history and examination. We pay particular attention to middle ear infections, as susceptibility to infection may delay or prevent implantation. A CT scan is carried out under anaesthesia for young children. Electrical stimulation of the promonotory is only done for children 10 years and above.

In stage 3, the audiological assessment aims at establishing the hearing threshold levels and determining how effective the hearing aids are. Establishing the hearing thresholds in very young children is facilitated by using a steady state evoked response (SSEP) technique we have developed in the Department of Otolaryngology (Rickards & Clark, 1984). This technique involves presenting amplitude modulated (AM) and/or frequency modulated (FM) sounds with different carrier frequencies. A Fourier analysis is carried out on the evoked responses, and objective criteria are set for establishing thresholds at each carrier frequency. The thresholds are specific for the regions excited by the carrier frequencies. It is an especially useful procedure in measuring the thresholds for low frequencies which can still be present when the high frequencies are lost. Assessing hearing thresholds at low frequencies is difficult with standard ABR techniques, but can be successfully carried out using the SSEP procedure referred to above.

In stages 3 and 4, we assess all aspects of a child's ability to communicate. This means assessing speech perception, speech production, language skills and pragmatics (their ability to converse).

Following this speech and language assessment, the children undergo a preoperative training program so they can learn to use any residual hearing. This program also gets them used to the auditory/oral training they will receive when they get an implant.

Finally, the assessment of the child is reviewed by the management team and ethics committee before implantation.

**Parent Guidance**

We would like to emphasize that, preoperatively and postoperatively, the parents need counselling. This help includes information on the procedure and discussion of their emotions during both the preoperative and postoperative periods. The clinician has a responsibility to address with the parent such issues as the potential and limitations of the device, the range of results obtained with children who currently have the implant, the importance of factors such as motivation (the child's and their own), and the effect of age at onset of deafness and current development of speech and language on the child's prognosis. Time is needed to help the parents understand and accept the effects of implantation. The time available before the operation is a valuable time for developing rapport with the parent.

Parents are also encouraged to have contact with parents of children who have already received the implant. This is accomplished through the Parents' Support Group which meets on a six-weekly basis. This forum allows parents to develop friendships and sources of information: valuable support in times of need. Luterman (1979, 1984) notes that the most valuable service a professional can give a parent is to put them in touch with other parents. The parents themselves recognise the value of sharing experiences and emotions, and supporting each other.

An important component of the preoperative period is preparing the child for the operation. The parents may be reluctant to talk with their child about the operation, fearing the child may become anxious about the events.

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They need to be encouraged to discuss the events to ensure that the child is prepared for a hospital stay, an operation, a bandaged head and some pain. It is especially relevant that the child knows his/her hair will be shaven, since this will occur under the anaesthetic. This can severely affect their self-concept immediately postoperatively, and they need to have the opportunity to adjust to the idea beforehand. Preparation for hospitalisation generally includes a visit to the children's ward a couple of weeks before being admitted. Often the parent will take photos which can be incorporated into a special "hospital" book, or pinned up on the wall at home. Some parents put up a calendar with each of the steps marked on it so that the child can anticipate the day on which he/she goes to hospital. The clinician, child and parents also use the books designed and supplied by Cochlear Corporation to help the child understand the operation. The children may also meet with other children who have had the implant, and they can have the opportunity to play with a doll who wears a "speech processor" and the external parts of the device.

Despite this preparation, the clinician still needs to be aware of the possible psychological effects on the child. One child, an eight year old, refused to take her hat off for weeks after the operation. Another refused for three months to talk with the clinician who had visited him in hospital. Another disliked coming to the hospital for about six months following hospitalisation and the start-up. Everything should be done to minimise these reactions, but it is not easy to predict how a particular child is likely to respond to the changes in his/her life — temporary loss of hair, wearing the device, new auditory sensations, interest in the device from other people, to name a few — and each child's reactions need to be treated with understanding. Prior to the signing of the consent form, the parent is informed of the possible reactions. This is especially relevant if the lesion is in the temporal bone, the only bone that is mobile at birth. Recovery is not complete until the bone has expanded, by months to years. This can have a long-term effect on the child, which can be severe, even requiring medical intervention. This is illustrated in Figure 4. A result of this finding is the distance between the round window and fossa incudis does not change from birth to adult life. This is illustrated in Figure 5 (Webb et al, 1990). In addition, we leave a redundant loop from this fixation point to the package to allow for temporal bone growth.

Because the decision to implant is based on many factors, it is often not until after a lengthy period of (re)habilitation that the clinical team can decide whether to offer the parents the option of the cochlear implant operation. This apparent indecision on the part of the clinic can be very frustrating for the parents, who have possibly already decided for themselves that they want their child to receive the implant, and want to get it over and done with as quickly as possible. They require a great deal of support during this time from a clinician who is willing to listen to their concerns, and who can provide them with information about the implant and their child's progress (Rowland et al, 1990a).

**Surgery**

The surgery is basically similar to that in the adult, but needs to be modified because the temporal bone is smaller and the bone is thinner. The first point to emphasize is that the incision needs to be the same size as in an adult, and therefore it will appear relatively larger. The second point is that it may be necessary to drill bone down to dura to make the bed deep enough to accommodate the receiver-stimulator package. The third point is that the lead wire should be fixed superiorly and not to the mastoid tip as the latter area expands more rapidly during maturation. With regard to fixation, ensure that there is a redundant loop between the package and fixation point, and another redundant loop between the fixation point and round window. These redundant loops are important in allowing for head growth so that there is no movement of the electrode in the cochlea or the receiver-stimulator package.

To minimize the effects of head growth, we have been studying the growth of the temporal bone to find out where we should place the ties (Shepherd et al, 1989). One important finding from the study is that the distance between the round window and fossa incudis does not change from birth to adult life. This is illustrated in Figure 4. As a result of this finding we are now carrying out a clinical and experimental trial to see whether we can adequately fix the electrode to the floor of the antrum in the region of the fossa incudis. The tie is illustrated in Figure 5 (Webb et al, 1990). In addition, we leave a redundant loop from this fixation point to the package to allow for temporal bone growth.

**FIG. 4.** (Shepherd et al, 1989) The distance between the round window and fossa incudis versus age.

**Auditory Training and Education**

Three weeks after their surgery the children are ready to have the stimulus thresholds and maximum comfortable listening levels for each bipolar electrode pair mapped into their speech processor. When presenting children with electrical stimuli for the first time great care is taken to see that they don't receive a stimulus that is too strong. Thresholds are determined by gradually increasing the
stimulus intensity and getting the child to respond in some way by, say, placing a block on a spike when they hear a sound. The maximum comfortable levels are determined by slowly increasing the intensity of a speech stimulus, while the child is distracted at play, until they indicate that it is uncomfortable. When the speech processor is programmed for the child, we commence training, and endeavour to improve his/her speech perception, speech production and language skills. This is facilitated with the MSP speech processor recently released by Cochlear Pty Limited. This is shown in Figure 6 beside the standard device. It is smaller and lighter and much more suitable for children. It also performs better than the previous WSP III processor (Dowell et al. 1989, 1990).

In training children to use the cochlear implant there are two main points to consider: firstly, the children should ideally be educated by auditory/oral methods. This means they should be taught by methods which maximize the use of their new auditory information from the implant, and they should be taught to combine their auditory skills with lipreading. It is less likely that an implant could be used effectively in a signing environment, especially with sign language of the deaf (Auslan). The second important point is that children with implants, as well as other deaf children, should be trained by speaking to them naturally using normal conversation.

### Audiological Assessment

Currently (March 1990) we have implanted 13 children of 12 years and under, as well as seven teenagers. In our group of 13 children there are five who are verbal and eight who are pre-verbal. The children who are verbal have sufficient language to carry out speech tests. The children who are pre-verbal do not have language for standard speech testing. Our children are at different stages of assessment and we present the results for the first four verbal (Figure 7) and first three pre-verbal children (Figure 8).

The results for BKB (Bench-Kowal-Bamford) sentences and AB (Arthur Boothroyd) words for cochlear implant plus lipreading, hearing aid plus lipreading, and lipreading

### Child Aetiology Age at onsets (years) Age at implantation (years) Educational program

<table>
<thead>
<tr>
<th>Child</th>
<th>Aetiology</th>
<th>Age at onsets</th>
<th>Age at implantation</th>
<th>Program</th>
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<td>Auditory</td>
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<tr>
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<tr>
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<td>8.0</td>
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<tr>
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<td>Auditory / Oral</td>
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</table>

### FIG. 6. The WSP III speech processor (presents fundamental frequency — F0, first formant frequency — F1; second formant frequency — F2), next to the MSP speech processor (presents F0/F1/F2 and high frequency spectral peaks — HFSP).

### FIG. 7. A summary of aetiology of deafness, age at onset, age at implantation and educational program for our first four verbal children

<table>
<thead>
<tr>
<th>Child</th>
<th>Aetiology</th>
<th>Age at onset (years)</th>
<th>Age at implantation (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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### FIG. 8. A summary of aetiology of deafness, age at onset and age at implantation for our first pre-verbal children.
The BKB sentence scores for our first four verbal children for: lipreading alone, and hearing aid plus lipreading — preoperatively; and lipreading alone, and cochlear implant plus lipreading — postoperatively.

The AB word test (phoneme) scores for our first four verbal children for: lipreading alone, and hearing aid plus lipreading — preoperatively; and lipreading alone, and cochlear implant plus lipreading — postoperatively.

FIG. 9. The BKB sentence scores for our first four verbal children for: lipreading alone, and hearing aid plus lipreading — preoperatively; and lipreading alone, and cochlear implant plus lipreading — postoperatively.

FIG. 10. The AB word test (phoneme) scores for our first four verbal children for: lipreading alone, and hearing aid plus lipreading — preoperatively; and lipreading alone, postoperatively.

FIG. 12 (Busby et al, 1990) Receptive vocabulary scores for verbal child 1: observed scores versus age appropriate expected scores during pre and postoperative data collection times.

FIG. 13. Verbal responses for pre-verbal children measured over time post-implantation.

Finally, initial results for our first three pre-verbal children are presented. One method of assessing them is to measure the number of times they communicate with a sound or word rather than a gesture. The results for the three pre-verbal children are shown in Figure 13 (Rowland et al, 1990b).

Not only did the verbal children have improvements in speech perception and speech production but also with their language. The improvements in language over time for child 1 are shown in Figure 12 (Busby et al, 1990). From this it can be seen how the observed scores get closer to the expected age appropriate scores following cochlear implantation.

As can be seen, the children's verbal responses increased markedly following implantation. This is presumably due to auditory stimulation from the implant, but could also be due to a training effect. Further research is required to...
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develop assessment procedures to determine the benefits of cochlear implants in pre-verbal children.

Conclusion

In summary, we would emphasize that cochlear implants help profoundly deaf children to communicate, but results vary. Auditory/oral training is essential, and our clinical experience suggests that children will obtain better results if they receive an implant at an early age.

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