Most children who are diagnosed with a sensorineural hearing loss are fitted with hearing aids. The audiologist selects hearing aids on the basis of the child’s hearing loss and sets them so that they give the child as much amplification as possible to detect conversation. With consistent testing, hearing aid use, experience and auditory learning, many children can learn to use their residual hearing for speech and language learning.

However, for some children with a severe-to-profound hearing loss, hearing aids may not provide adequate benefit even after extensive experience and auditory learning. An acquired hearing loss resulting from illnesses such as meningitis or viral infections, can leave a child with total deafness. Children with auditory neuropathy also may not benefit from hearing aids. For these populations, the cochlear implant is an alternative. The implant is not a cure and will not restore hearing to normal levels.

Perhaps you are considering an implant for your child, or you simply wish to become informed about options that are available to you and your child. This paper is an introduction to cochlear implants. It includes: some information about the selection criteria for determining an implant candidate; information on how the implant works; and information on what it can provide for the user. Research is ongoing and changes are constantly occurring. It is important that you contact your nearest cochlear implant centre for any updated information that may be available. If you are not sure where to find a centre, you may contact CICS - Cochlear Implanted Children’s Support Group.

Cochlear implants were first introduced in the 1970’s to enable post-lingually deafened adults to perceive speech by electrically stimulating the auditory nerve. In 1980, the first child was implanted with a single-channel device. Now, with over twenty-five years of experience, cochlear implant manufacturers are focusing on stimulation rate and number of channels as they provide the best possible sound awareness for your child. Age of implantation has been lowered to one year and bilateral implants are becoming popular in some cases. Many implant centres have different requirements, so it is important to check with your centre for details.

I. Candidacy - How are implant candidates selected? Audiologic Factors

The most important selection criterion for determining if a child should receive an implant is whether the child has shown significant benefit from wearing conventional hearing aids. An aided audiogram for a candidate would show limited responses in the speech range; however, consideration also is given to children who have responses to sound, but who are unable to discriminate those sounds. Each person is different, and some will be able to function with limited aided responses, while others cannot utilise the sounds their hearing aids provide. Along with extensive behavioural testing, ABR (Auditory Brainstem Response) and OAE (Otoacoustic Emissions) will be done. An ABR test alone is not sufficient to determine if a child qualifies for an implant. Often an implant centre will require a child to wear traditional amplification for six months and to receive auditory training in order...
to determine if the hearing aids are beneficial. Recently, however, the desire to provide sound awareness when a child is very young has caused some implant teams to be less stringent in this requirement.

**A Family’s Expectations**
Another major consideration in implanting a child has to do with expectations. The family’s expectations as to what the implant can and cannot do need to be discussed. It is the job of the implant team to ensure that a family has realistic expectations for what the implant will provide and also for the ongoing commitment a family must have once the child is implanted. This commitment includes caring for and maintaining the implant equipment, continuing regular follow-up evaluations, and the biggest job of all - helping the child learn to use the implant to listen.

**Educational Programme**
The greatest success with the implant has been seen in children who are in educational programmes that emphasise the use of listening in all learning tasks. The cochlear implant is an auditory device that provides maximum benefit to children who receive intensive, auditory learning. Some auditory awareness is apparent before any training begins because the implant allows the child to detect speech. The meaning of speech sounds must then be learned. Real benefit is achieved when listening is integrated into all aspects of a child’s life.

**Physiological Factors**
How well a child is able to use the implant also is determined by physiological factors. For children who have considerable ossification (bone growth in the cochlea as a result of meningitis), or malformed cochleas, it is uncertain that all electrodes can be used. Surgeons can drill out the cochlea to insert as many electrodes as possible, and it has been found that even with the use of only a few electrodes, a child can benefit from the sounds he hears. Some children are diagnosed with auditory neuropathy which is the inability of the hearing nerve to transmit sound clearly. A cochlear implant can benefit these children because of the manner in which the nerve is stimulated by the sounds generated by the implant.

**Motivation**
A major factor determining the success of the implant is motivation. The attitude of the child who receives the implant is critical, as are the attitudes of the parents and teachers. Children need to feel positive about the implant and learn to depend on it.

Adolescents and teenagers may become non-users of the implant because of cosmetic reasons and peer pressure, or because they are not in an educational programme which is designed to work with young adults with cochlear implants. However, a young child’s attitude about the implant is easily shaped by the attitudes of her or his parents and teachers. Parents and teachers need to become knowledgeable about the implant. They must also have positive expectations that the child will learn to listen with it.

A number of factors have been mentioned that influence how much and how quickly a child will learn with the implant, and also what factors need to be addressed when considering who is
a suitable candidate to receive this device. To review, these are: the length of time between diagnosis of a hearing loss and receipt of the implant; the amount of bone growth or the malformation of the cochlea; function of the VIII cranial nerve (hearing nerve); a child’s educational programme; and the extent of support and involvement of parents and other professionals.

Because these factors can vary, it is difficult to predict how the implant will benefit a particular child. Many of these same elements are responsible for the wide range of performance seen among hearing aid users. When being considered for an implant, each child must be viewed as an individual. What precisely an implant will do for an individual can only be explained in terms of what it may “potentially” provide.

II. The Cochlear Implant and Its Parts

All cochlear implants are made up of: (a) external parts, which are worn outside of the body, and (b) internal parts, which are surgically implanted. The external parts consist of a microphone, a speech processor and an external transmitter. The microphone gathers the sounds, and sends them to the speech processor by a thin cord. The processor uses a “strategy” to code these responses, and then sends them back up the cord to the external transmitter, which sends that code through the skin to the internal components.

The internal parts consist of an internal receiver and the electrode array. The internal receiver lies just under the skin and connects to a delicate wire that extends into the cochlea. The electrical signal is carried down the wire to the cochlea, where the electrodes stimulate the auditory nerve fibres and the sound is transmitted to the brain.

Three cochlear implant manufacturers provide the implants used today. These are: Cochlear Corporation, Advanced Bionics and Med-El. Research has shown that all three devices provide excellent benefit and that no one implant company is superior to the others.

Microphone

Some cochlear implants place the microphone in a case that resembles a hearing aid and fits over the ear. On others, the microphone is placed directly in the external transmitter and fits against the head. Or, the microphone might be part of a small processor which is clipped to a shirt.

Speech Processor

Each cochlear implant has a body-worn speech processor, approximately the size of a box of crayons, or a speech processor which is encased in the behind-the-ear device which resembles a hearing aid.

The speech processor is like a small computer that uses different processing strategies to change
the sound from the microphone to an electrical signal. Each cochlear implant manufacturer has programmed various strategies into the processor and your child’s audiologist will use the one which is most appropriate.

**Transmitter**
The transmitter coil for all cochlear implants is worn above and slightly to the back of the ear. It contains a magnet that is attracted through the skin to a magnet in the internal receiver. Its purpose is to transmit to the internal magnet the sound that the speech processor has generated. The strength of the magnet can be varied so that it is comfortable for the child and yet does not fall off during average play.

**Electrode Array**
Electrode arrays vary according to the needs of the cochlear implant wearer. The array might be split to better fit a child whose cochlea has ossified because of meningitis, or it might be contoured to fit a child with Mondini malformation. Electrode arrays also come in different lengths, designed to provide the best transmission of the sounds of speech.

**III. What Will My Child Hear with a Cochlear Implant?**
Although receiving a cochlear implant does require a surgical procedure, it is not a “cure” which will restore a child’s normal hearing. The signal a child receives with the implant will be new and very different from what was received from his or her hearing aids. Many adult implant users describe what they hear through the implant as somewhat mechanical. In time, cochlear implant users report that speech becomes more “natural sounding.” A child must learn to interpret this new type of sound, and attach meaning to it. Just as children function differently with hearing aids, children with implants will vary in how well they are able to use their implants and how quickly they learn. THE IMPLANT DOES NOT BRING ABOUT “INSTANT HEARING” AND PERHAPS AT FIRST, ONLY SMALL CHANGES WILL BE NOTICED.

The ability to listen and make sense of what is heard must be developed over time. There will be no success with a cochlear implant without follow-up. The child will understand the meaning of sound only with appropriate training, and that is why it is critically important that comprehensive services and skilled teachers are provided. Research has shown that children in a school with a strong auditory emphasis will do best with their implant. Speech and language therapy with a trained therapist also is very beneficial.

It is logical to assume that because the cochlear implant provides an awareness of speech sounds, a person will be able to learn speech. However, “hearing” is not the same as “understanding.” Understanding occurs as a result of the ability of the nerve to transmit the sound clearly to the brain, and of the brain to make sense of that sound. Having a cochlear implant does not guarantee the ability to develop spoken language.

**IV. The Process of Obtaining a Cochlear Implant**
Each implant centre follows specific guidelines for the selection and follow-up of its patients. However, there can be great variability in procedure from one centre to another. Therefore, in this paper, the procedure or protocol for
implanting children will be explained in general terms. A children’s implant programme typically involves four components. They are: a Selection-Evaluation Procedure, Surgery, Initial Stimulation and Follow-up Evaluation.

**Selection -- Evaluation Procedure**

Typically, a parent makes the initial contact with an implant centre via a referral from another professional. The family will be sent an information packet by mail. A consultation appointment is set up to discuss realistic expectations, the device itself, the surgical procedure and rehabilitation process. At this time, an evaluation period is arranged to continue the selection process. The child and family go through a number of tests and counselling sessions with many different professionals. These sessions include medical, audiological, speech and language, educational and psychological evaluations.

During the Selection-Evaluation Procedure, the family comes into contact with a number of professionals who are members of a cochlear implant team. The information gathered at this time will allow the team to counsel a family and make recommendations. Parents should view themselves as equal members of the cochlear implant team through the selection and rehabilitation process.

**Medical Examination**

A complete medical examination is done including a thorough examination of the ears to confirm permanent sensorineural hearing loss. The otologist, a physician who specialises in diseases and surgery of the ear, also will check the status of the cochleas by CT scans; that is, Computerised Tomography. CT scans involve taking an x-ray which enables the physician to see a picture of the inner structures of the ear, particularly the cochlea which is located in the bony area of the skull behind the outer ear. The physician also checks for ossification or bone growth, which often occurs as a result of having meningitis, or for Mondini syndrome, which is an incomplete formation of the cochlea. Both of these occurrences may be factors in planning the surgical procedure since the cochlea must accommodate the electrode array. Even if a child’s cochleas are not normal, the surgery can sometimes be done using the contour or split electrode array.

**Audiologic Testing**

An audiologist will spend a great deal of time evaluating the child and counselling the parents. Parents will become acquainted with the equipment involved, and extensive information will be shared as to what the implant can and cannot do. Often, families will have a chance to meet and talk with the family of an implanted child, with the child himself, or with an implanted adult. The audiologist will conduct a number of tests including a standard hearing test with and without hearing aids. If the child has not been appropriately aided, a trial period of hearing aid use with auditory training might be suggested to determine if a child will receive benefit from them. A number of auditory tests are given to establish a baseline for the progress a child is expected to make after learning to listen with the implant. This information will be used to determine the progress a child actually makes after receiving training with the implant. Much of the test information gathered serves another function as well; it is used for research purposes.
Psychological, Educational and Speech-Language Evaluations

In addition to a medical examination and audiologic testing, the family meets with a psychologist who interviews the parents and assesses the child on cognitive, personality and behavioural measures. The family also receives educational counselling about school placement and services along with suggestions for maximizing auditory skills development. The child is seen by a speech-language pathologist who administers speech and language tests.

None of these professionals alone can determine candidacy for an implant. Each is part of a complete team, and that team includes the parents. When all of the assessments are complete, the team meets and discusses results and overall prognosis. The parents, as part of that team, provide a necessary contribution in this decision-making process.

Surgery

If the child is found to be a suitable candidate for the implant, and if the parents decide to implant their child, surgery will be the next step. The surgical procedure of implanting the internal receiver and electrodes typically lasts two to three hours. It requires general anaesthesia, however the child often is able to return home the day of the surgery. If the child remains in the hospital, it is only for one night. The child’s head is shaved only in the area behind the ear where the incision is made and the hair will grow back naturally over this area. The surgeon uses a drilling procedure to reach the inner ear. The electrodes are inserted into the cochlea. The internal receiver is anchored to the mastoid bone (the bone behind the ear) and the incision is closed. Recuperation from the effects of general anaesthesia takes about one day. After a complete healing of the area around the implant (about 3 to 4 weeks) the child receives the external equipment.

Many parents express concern that if their child is implanted at a very young age, the inner ear area will grow and the electrodes will be pulled out. The cochlea is adult size at birth, and although the area between the cochlea and the receiver can grow slightly, the surgeon leaves enough wire to accommodate that growth.

Initial Stimulation Session

Many parents say that their child will be “hooked-up” or “turned-on” when they return to the centre one month after surgery to map or programme the implant. Audiologists and physicians refer to this as the “initial stimulation,” and you might also want to use this term when you refer to this session.

The initial stimulation session involves fitting the child with the external equipment; that is, the external transmitter coil and the speech processor. A quick medical check is done to ensure that the incision has healed and the swelling has gone down. The audiologist selects a magnet of appropriate strength to align with the implanted internal receiver.

It is ideal for family members and other significant people who interact with the child on a regular basis to observe the initial stimulation process. The child’s classroom teacher and speech
therapist also could benefit from participating, and they would be a source of valuable input. Parents and teachers also receive a Patient Kit and are instructed on how to care for and test the equipment. Information is shared regarding precautions, warranties and repairs. Parents also are given ideas for developing listening skills to be done at home. Since the implanted child now has a chance to be successful at listening, it is important that parents and teachers develop new expectations for the child to listen with the implant.

The audiologist will use a computer to programme the speech processor by generating sounds which are much like a hearing test. However, now the audiologist is looking for the softest levels and the most comfortable levels of response for each electrode or electrode pair. The responses obtained are called the “map.”

Many very young children who have no knowledge of sound are not able to provide this information. The audiologist can then use Neural Response Telemetry to map the implant.

Each of the manufacturers’ speech processors has multiple programmes, so the audiologist can set them for different stimulation settings (maps), and the parent may change them over the first few days to determine which is best for the child.

During the first few weeks and months, the child will return for continued mapping. This is because the sensitivity of the auditory nerve can change over time as it becomes accustomed to stimulation. The initial map may be changed many times until the most appropriate map has been obtained.

An Orientation To Sound
The next step in the mapping process is an orientation to sound for the child. The audiologist will repeat many of the initial evaluation tests, which will indicate if the child is now able to respond to: presence and absence of sound; environmental sounds or noisemakers; long and short speech sounds; fast and slow rhythms; and one- versus two-syllable words.

An audiologic evaluation will be part of this process. With a cochlear implant, a child will respond at approximately 20 to 35 dB across frequencies of 250 to 4000 Hz. Therefore an audiologist would report that these responses indicate the ability to perceive the broad spectrum of speech at normal conversational levels. It is important to be aware, however, that a cochlear implant does not provide normal hearing levels.

Parents and educators are an integral part of orienting the child to sound. It is imperative that the child be in a school programme that is designed to meet his or her needs, and that parents are aware of the importance of their roles in working with the child at home. Success in understanding the meaning of sound does not stop with the audiologist, but continues with the school and the family.

Follow-up Programme
The cochlear implant requires follow-up visits at one, three, six, twelve and eighteen months from...
the time of the initial stimulation. More frequent follow-up visits may be necessary. During a follow-up visit, any necessary adjustments to the processor are made. Then audiologic, speech and language testing are repeated. Some additional auditory training may be done as well. Each follow-up period may require scheduling a two-to-three day visit at the implant centre.

V. Safety Issues and Risks

Extensive research has been done on the implant to determine its safety and effectiveness. One safety issue involves the effect of prolonged electrical stimulation with the implant. Adult implant users have been carefully monitored since 1973 and children since the 1980s, and no adverse affects have been noted.

Problems with breakdowns of the external equipment have been reported, and this can occur from electrostatic discharge in dry climates. The processor can easily be re-mapped if this occurs, and precautions against electrostatic discharge can be taken.

Failure of the internal equipment has occurred on occasion from a blow to the head. Parents are advised to keep their child from playing hard, contact sports to protect them from this possibility.

The risks associated with implant surgery are those that are common to most kinds of ear surgery. Some effects that could potentially occur include: infection, pain in the area of the coil, coil extrusion and facial nerve weakness or paralysis which may be a temporary result of drilling close to the facial nerve. Other risks can be head noise or tinnitus and dizziness. Because implant surgery requires general anaesthesia, it has the same potential risk as with any surgical procedure.

VI. Auditory Learning and Educational Programming with the Cochlear Implant

We have already talked about what the implant can and cannot do for children, and we have discussed the potential benefits that an implant can provide. Once surgery and the mapping process have been completed, it is the family of the implanted child and his or her teachers who are faced with helping the child achieve long-term benefits from the implant. It is important that parents and educators work together toward the same goal - to help the child learn to listen with the implant.

To this point, much work has been done in the testing booth or therapy room to get the child started with the implant. But the ultimate goal is to integrate listening into all aspects of a child’s life so that the child relies on the implant for communication and learning. The ability to perform auditory tasks will only be beneficial if the child is able to generalise these skills to natural contexts. It will have little value for a child to be able to tell the difference between a low pitched and high pitched sound in therapy if the generalisation cannot be made to discriminate pitch and know whether it is mummy or daddy who is calling the child’s name.

Structured listening tasks are necessary with trained professionals, especially in the beginning stages
of implant use. A child needs to experience small successes with the implant before spontaneous or incidental listening can be expected. Structured, as well as incidental listening, must be a part of a child’s daily experiences. This means that teachers and parents must have consistent expectations throughout the day. Listening should not be expected only during “lesson time” or “auditory training time.”

Remember that the implant enables a child to detect sounds, but discrimination and understanding what is heard requires experience and training. A child’s auditory development with the implant will follow the same steps as the child’s development with hearing aids. There should be no differences in the types of activities that the classroom teacher and parent use to develop auditory skills.

VII. The Future of Cochlear Implants
Efforts are continuously being made to improve the implant. The adults and children who have been implanted so far provide important information for researchers to help them make the implant better. Improvements have been made with regard to miniaturising the speech processor and changing external equipment features to reduce the cost of replacing and repairing broken parts. Efforts towards improving the implant’s perceptual capabilities are ongoing.

Bilateral cochlear implants are now becoming more common. With an implant for each ear, localising the direction of sounds is easier. Also the brain can more easily process and understand speech when it comes from both ears.

Parents naturally want the best and newest device available. However, it is important to know that surgery to “switch” to a more up-dated implant is not currently encouraged. Children become accustomed to and comfortable with the sound generated by their implants and changing implants could make them uncomfortable. During the course of a lifetime, it might be suggested that a new implant be obtained in order to derive more benefit. However this would not be in the near future.

Furthermore, parents are not encouraged to wait for a newer device. Learning language occurs when a child is young. If sound awareness is not provided in the early years, an opportunity which cannot be regained is missed. If the decision is made to get a cochlear implant, the time to do it is now.

VIII. A Final Note
It is hoped that the information provided here gives you a basic understanding of the cochlear implant. Whether you are considering an implant for your child or not, it is important that as parents of a hearing impaired child, you become knowledgeable about all the options that are available to you. The more you become informed, the better you will be able to meet the varied needs of your child.

If you are considering an implant for your child, keep in mind that your child is unique. You know your child best and any decision you make should reflect your child’s individual circumstances.
Always remember that if you become involved at a cochlear implant centre, you are a key member of a team, and that the decision to implant a child is a team decision. If you are the parent of a child with a cochlear implant, it is important to remember that of all the people involved, you have the most vital role in fostering your child’s educational development and success as an implant user.

**Manufacturers of Cochlear Implant Devices**

**Advanced Bionics Europe**
76 Rue de Battenheim
68170 Rixheim/Mulhouse France
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E-mail: europe@advancedbionics.com
Website: www.bionicear-europe.com

**Cochlear Europe Ltd**
22-24 Worple Road
Wimbledon
London SW19 4DD
Tel: 020 8879 4900
Website: www.cochlear.com

**Additional Sources of Information**

**AG Bell Association For The Deaf**
23417 Volta Place
N.W. Washington, DC2007-2778
USA
Tel: +(202) 337 8767
E-mail: agbell2@aol.com
Website: www.agbell.org

**Cochlear Implanted Children’s Support Group (North)**
Hilary French
11 Wearside Drive, The Sands
Durham City DH1 1LE
Tel: 0191 386 1112

**(South)**
Tricia Kemp
4 Ranelagh Avenue
Barnes, London SW13 0BY
Tel: 0181 876 8605

**DELTA (Deaf Education through Listening and Talking)**
The Con Powell Centre
3 Swan Court, Cygnet Park
Peterborough PE7 8FD
Tel: 0845 1081437
E-mail: enquiries@deafeducation.org.uk
Website: www.deafeducation.org.uk

**Listen Up**
A huge library for researching any question relating to hearing impairment.
E-mail: kay@listen-up.org
Website: www.listen-up.org

**Meningitis Trust**
Fern House, Bath Road,
Stroud, Glos. GL5 3TJ
E-mail: info@meningitis-trust.org
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15 Dufferin Street
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