

# 10

## Surgery

### Overview

The surgical implantation of a cochlear prosthesis requires adhering in the first instance to the three cornerstones of modern ear surgery elaborated by Shambaugh (1959): (1) mastery of the complicated anatomy of the ear, (2) meticulous asepsis, and (3) magnification under the operating microscope. In addition, skill in the use of fine drills is essential. The electrode bundle must be inserted atraumatically into the inner ear as close as possible to the auditory nerve fibers. The receiver-stimulator package, which is connected to the electrode bundle, needs to be accommodated in an optimal position in the skull.

In implanting the electrode array and the receiver-stimulator package, great care must be taken, as there are more nerves and vessels concentrated in a small area of the temporal bone than elsewhere in the body. The mastoid bone is partly filled with air cells that have entered from the middle ear cleft at 34 weeks post-gestation (Bast and Anson 1949). These cells provide space for the placement of the receiver-stimulator package and lead wires. Nevertheless, just behind the mastoid air cells, the skull often needs to be drilled down to the dural lining of the brain to accommodate the package without it protruding too far above the surface of the skull, and so producing a bulge. Partial removal of the air cells provides a route from behind the ear to the middle ear, and thence to the inner ear. To approach the inner ear or cochlea, an opening needs to be made into the middle ear from behind by drilling between the vertical segment of the nerve to the facial muscles (facial nerve) and a nerve bringing taste sensations from the tongue (chorda tympani nerve). The course of these nerves can vary, and this needs to be taken into consideration to avoid injury.

Finally, the skin must be closed over the receiver-stimulator package thus not leaving a path for the entry of infection. This could occur with percutaneous stimulation with a plug and socket. However, in both cases there is a passage for infection to enter from the nose via the eustachian tube.

## Brief history

An intracochlear electrode inserted into the scala tympani via an opening at or near the round window was the approach favored by House and Urban (1973), Michelson and Schindler (1981), Clark, Patrick et al (1979), Clark, Pyman et al (1979, 1984), and Burian et al (1986). More recently a separate opening anterior to the round window has become the standard approach. Previously Simmons (1966) inserted electrodes into the modiolus, and Chouard and MacLeod (1976) carried out a procedure drilling a series of holes directly into the cochlea through a middle fossa craniotomy, then via the middle ear, before adopting the scala tympani approach (Lacombe et al 1984). Extracochlear electrodes have been either lodged at the round window membrane as described by Burian et al (1986) and Portmann et al (1986), or placed in the bone over the cochlear turns beneath the medial wall of the middle ear (Banfai et al 1984).

The mastoidectomy and “facial recess” approach to the middle ear referred to above and described by Myers and Schlosser (1960) was the route to the round window favored by House and Urban (1973), Clark, Patrick et al (1979), Eddington et al (1978), Parkin et al (1985), Burian et al (1986), Portmann (1986), Chouard and MacLeod (1976), Lacombe et al (1989), Eddington et al (1978), and Lacombe et al (1984). A trans-external canal approach was advocated by Simmons (1966), Michelson and Schindler (1981), and Banfai et al (1984). In the latter cases problems with extrusion of the lead wires required them to be buried in a groove cut in the posterior canal wall. This did not always resolve the difficulty, and surgeons then obliterated the external canal (Banfai et al 1986).

A percutaneous plug was the external link in a number of early devices, such as those of Simmons (1966), Chouard and MacLeod (1976), Michelson and Schindler (1981), Banfai et al (1984), and the Utah group (Eddington et al 1978), whose research led to the Symbion device (Parkin et al 1985). However, an inductive electromagnetic link was used at the beginning of clinical trials by House and Urban (1973), Clark, Pyman et al (1979), and Burian et al (1986). In these cases the internal receiver system was stabilized in a bed in the bone above or behind the mastoid and it contained an antenna that was activated by an external aerial applied to the overlying skin. A percutaneous link was superseded by an electromagnetic transcutaneous link through intact skin by Lacombe et al (1984) and Banfai et al (1986), due to problems with infection and instability with the former. The history of the surgical development is also outlined in Webb et al (1990).

## Aims

### *Position Multiple Electrodes Close to the Auditory Nerves*

The first aim of implantation is to position multiple electrodes in the cochlea close to auditory nerve fibers so that separate groups can be excited to convey essential

speech frequencies. The fine temporal and spatial patterns of stimulation required for improved temporal coding and musical appreciation are also likely with the precise placement of multiple-electrode arrays.

### *Implant Electrode with Minimal Trauma to the Inner Ear*

The second aim is to implant electrodes with minimal trauma to the inner ear. Any injury leading to loss of spiral ganglion cells and auditory nerve fibers is especially to be avoided. Studies described in Chapter 3 have shown that trauma of the basilar membrane and fractures of the spiral lamina are likely to do this. Trauma to these and other structures may also lead to excessive fibrous tissue and new bone formation that may affect the electrical field and stimulus current levels.

### *Locate the Receiver-Stimulator to Allow Optimal Use of a Microphone, Speech Processor, and Transmitting Coil*

The third aim is to locate the receiver-stimulator package so that the microphone, speech processor, and transmitting coils are close to each other; the microphone is close to the ear; and the lead wire from the package to electrode arrays in the cochlea is as short as possible.

### *Implant Receiver-Stimulator to be Unaffected by Growth Changes*

The fourth aim is to implant the receiver-stimulator in children so that growth changes in the temporal bone will not extract the array from the cochlea. The greater part of this growth is in the first two years of life. Consequently, this aim is most critical in this age group. This was discussed in more detail in Chapter 2.

### *Implant Operation Performed Safely*

The fifth aim is to maintain the highest standard of surgical care as well as audits of results so that prospective patients can be reassured that there are minimal complications. This applies in particular to the incidence of middle ear infection, labyrinthitis, and meningitis. For this reason, in addition to the initial otological and medical examinations, the patient should be reviewed shortly before surgery in case medical conditions have developed in the interim.

## Fundamentals and Clinical Practice

The fundamental principles of surgical techniques apply as much to cochlear implantation as to surgery in other regions. The techniques need to be adapted to the special anatomy and procedures.

### *Preoperative Measures*

Preoperative surgical management should focus on measures to prevent infection. This is more frequent when implanting a foreign body and is discussed below and in more detail by Lew and Waldvogel (1998). Infection with the implantation of a foreign body is more likely, as the material provides a home for the organisms and the neighboring tissue is less accessible to antibiotics (Lew and Waldvogel 1998). Postoperative infection is a serious complication that could lead to failure of the operation. Infection within the inner ear will damage and destroy the auditory nerve fibers (Clark 1975, 1977). A wound infection may require the device to be explanted before it can be controlled. Any infection in the wound or middle ear could lead to meningitis, also occasionally seen following a stapedectomy (e.g. Palva et al 1972; Benitez 1977).

The preoperative measures to prevent infection described below were outlined in detail in the surgical training manual developed by the Department of Otolaryngology at the University of Melbourne in 1980.

#### Preliminary Patient Preparation

The patient's skin is a major source of bacterial contamination in clean wound operations. Any existing acute or chronic infection in the area (including the ear, the skin, and the respiratory tract) must be controlled. In addition, potentially pathogenic organisms in the ear, nose, and throat should be eradicated. Therefore, swabs should be taken from the external auditory canal, the postauricular sulcus, and the nose, and topical antibiotics or antiseptics applied if necessary. On the night before surgery, the nursing staff should wash the patient's hair with an antiseptic shampoo. Hayek et al (1987) found a reduction in infection rate with chlorhexidine (9%) versus normal bath soap (12.8%). The external auditory canal should be inspected and if necessary cleaned.

#### The Operating Theater

The operating theater should meet high standards of asepsis and cleanliness. This is necessary, as the implantation of a foreign body in a hip or knee replacement is associated with a significant postoperative infection rate. The infection rate for hip replacements by Charnley (1972) was initially 7% but fell to 0.6% with air filtration and antibiotics. For cochlear implantation, an effective air filtration system, therefore, is required. A laminar flow unit, either horizontal or vertical, is valuable, and was used in the theater of the Royal Victorian Eye and Ear Hospital for the first 15 years to ensure that postoperative infections were kept to an absolute minimum (Clark, Pyman et al 1980). Regardless, a high standard of sterility must be maintained by all personnel in the theater with regard to instruments, drapes, and their own dress and movements. The number of people in the theater should be limited, and movement in and out minimized. Glove powder should be thoroughly washed off, as it may contaminate the wound and the cochlea and induce a foreign body reaction (Clark, Pyman et al 1980).

### Patient Preparation

The hair should be clipped on either side of the proposed incision. This is preferably done in the anesthesia room. Then either a wet shave with foam rather than a brush, or a depilatory cream can be used (Zentner et al 1987). Studies have shown that infection is lower with either a depilatory cream or leaving the hair closely clipped (Seropian and Reynolds 1971; Cruse and Foord 1973). The hard chitinous surface of a hair is easier to clean with the antiseptic rather than the skin in which it grows. Minimal removal of hair (approximately 1 cm on either side of the incision) was undertaken by Roberson et al (2000) on 46 patients, and no wound infections occurred. The cosmetic benefits were ranked more highly by the parents of children than adults.

The patient is then moved into position in the theater, and an appropriate antiseptic liberally applied to the side of the head including ear, external canal, the face (eyes being protected), and the neck. A sterile plastic drape is applied to the operation site and face. The electrodes to monitor any facial nerve stimulation are attached to the skin around the orbit and cheek. A sump to collect irrigating fluid spilling over from the wound is then put in place.

### Antibiotics

A broad-spectrum antibiotic cover for the operation is important, as the colonization of a foreign body by even a small number of bacteria can lead to sepsis. The antibiotic is administered intravenously at the beginning of the procedure, with tissue levels peaking about 1 hour later when the inner ear is opened and implanted. It is administered again at the end of the operation to provide a further cover. It will be required postoperatively if there is any suggestion of a wound infection.

### *Incision*

The incision is made with a knife, although some surgeons use a cutting diathermy. The use of cutting diathermy in an area of cosmetic importance is contraindicated as it causes scarring, which can be excessive as keloid formation.

### Fundamentals

The fundamentals outlined below provide adequate exposure, cosmesis, rapid healing, and no extrusion of the package.

#### *Exposure of Underlying Tissue*

The incision must provide an adequate exposure of the surgical anatomy, and be easily extended if it is necessary to manage anatomical variations or complications. Sufficient mastoid bone should be exposed so air cells can be removed to provide access for an opening to be drilled into the middle ear from behind (posterior tympanotomy). This allows the cochlear window (round window) to



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Cochlear Implants

Fundamentals and Applications

Clark, G.

2003, XXXVIII, 831 p., Hardcover

ISBN: 978-0-387-95583-4