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Preliminary communication

The Hannover Auditory Brainstem Implant: a multiple-electrode prosthesis

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The cochlear implant has been shown for some years to be very successful in the treatment of profoundly deaf patients. Cochlear implantation is, however, only beneficial to those patients whose deafness is located in the inner ear. In Hannover to date we have performed implantations in 250 patients, including 61 infants and children using the Nucleus 22 mini-implant.

During the past several years, we have found that the "conventional" cochlear implant will not work if the etiology of deafness is due to a tumor in the inner ear canal or cerebellopontine angle or in cases with transections of both acoustic nerves. Such patients are candidates for a central prosthesis or auditory brainstem implant. In 1964, Simmons and co-workers [5] published their preliminary results of electrical stimulation of the acoustic nerve and inferior colliculus in a single male subject. Twenty years later the staff of the House Ear Institute published their data on this subject [1–3, 6, 7]. Important questions which have been raised about using a central prosthesis include where optimally to place the stimulation electrodes, how many electrodes should be used, what is the size and access to the stimulating area and what is the optimal stimulation strategy for this type of prosthesis. Additionally, consideration must be given to the maximum current density that can be used with physiological safety.

We have now studied the literature in attempting to formulate principles for clinical use of a centrally placed cochlear implant. Both from an anatomical and physiological point of view, the cochlear nucleus appears to be optimum for the placement of stimulating electrodes. The cells of the cochlear nucleus can be found in the floor of the lateral recess of the fourth ventricle and on the surface of the brainstem close to the entry of the acoustic nerve. In previous studies, McElveen and co-workers [4] showed that the surface of the ventral cochlear nucleus has the size of 3 to 8 mm. Surgical access to this area can be achieved through transmastoidal or suboccipital approaches. Both approaches give reasonable exposure, although the procedure of choice will depend on such anatomical considerations as the location of a resected tumor or one that is removed in the same operation prior to implantation. Alternatively, both approaches may be used in combination. A third possibility is placement of the electrode in the fourth ventricle. An osteoplastic median suboccipital craniotomy can be done by opening the mid-line of the neck to access the fourth ventricle. This last approach can be chosen in case of scar tissue problems in the cerebellopontine angle due to previous surgery.

Based on the various anatomical and surgical observations reported, we have developed a prototype of a central prosthesis as an investigational device with the assistance of Cochlear Ltd. (Sydney, Australia). The construction of our cochlear nucleus prosthesis is based

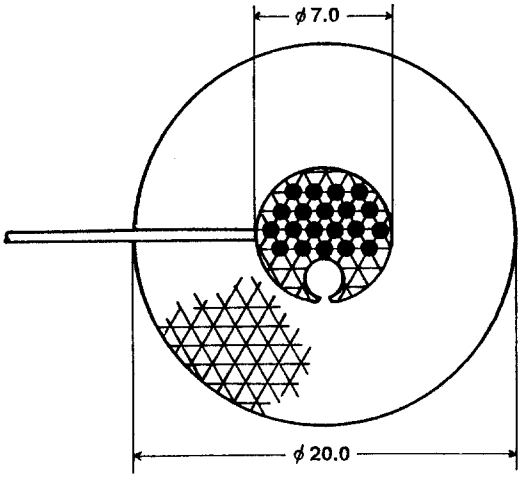

Fig. 1. The Silastic carrier for the 20 electrodes. The carrier is situated on a plate of Dacron mesh

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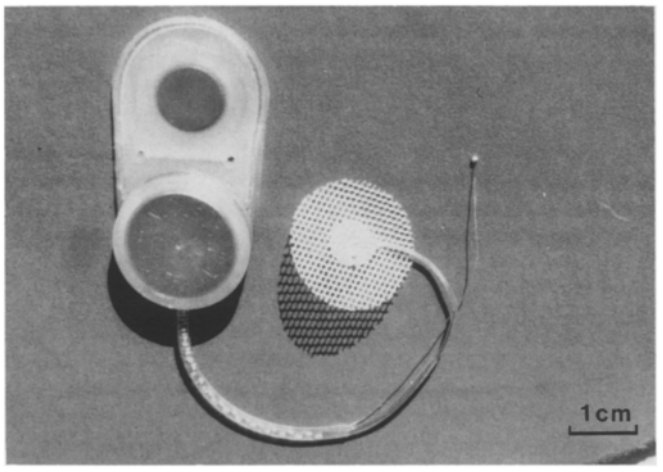

Fig. 2. The construction of the implant is based on the standard Nucleus mini-stimulator

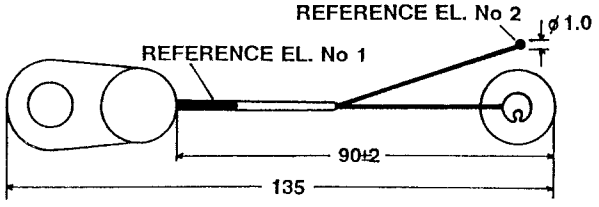

Fig. 3. The stimulator with the two reference electrodes connected. Electrode no. 1 is formed as a spiral wrap around the electrode lead while no. 2 is in the shape of a 1-mm platinum ball

on the standard Nucleus mini-receiver commonly used for intracochlear stimulation. The prototype device is equipped with specially designed electrodes. Twenty platinum electrodes are assembled inside a Silastic carrier 7 mm in diameter (Fig. 1). The surface of each electrode is a round plate with a diameter of 0.6–0.7 mm. This narrow dimension ensures that the maximum charge density of 40 $\mu C/cm^2$ per phase is not exceeded, particularly since this amount has been determined by previous research to not damage neural tissue. The active surface of each electrode is flashed with the surface of the silastic carrier to avoid damaging effects of pressure concentration. The active electrodes are situated on a plate of Dacron mesh (Fig. 2). The remaining stimulator outputs are connected to two reference electrodes. One is formed as a spiral wrap around the basal part of the electrode lead close to the receiver/stimulator and the second one is in a shape of a 1-mm platinum ball from a flexible lead (Fig. 3). The dacron mesh around the active electrode array can be trimmed during operation. Fixation in situ can be achieved by using Gelfoam or fibrin glue to fix the dacron mesh with surface electrodes onto the desired site of stimulation.

The large number of electrodes in the main electrode array allows the surgeon to select out the most useful electrodes for speech discrimination. There is also great flexibility in the Nucleus mini-22 device stimulator in that different modes, combinations of electrodes, pulse widths and rates can be accessed to achieve the optimal stimulation strategy.

The addition of two references electrodes to use in combination with the 20 active ones in the device should provide greater programming flexibility. The device utilizes transcutaneous transmission, although it could be equally useful to have a percutaneous plug or pedestal to enable direct transmission and research speech processing to be done clinically.

From the surgical point of view, the construction of the main electrode array allows it to be customized by enabling alteration of the shape of the dacron flange as well as the final shape of the Silastic carrier. For this reason, the device should be able to be used in all three surgical approaches to the brainstem. We recognize that we are just in the preliminary stage of our work but hope that we will be in the position to provide more information on our findings with this device in the near future.

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