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Physiological Basis for Cochlear and Auditory Brainstem Implants

Introduction

Cochlear implants are now the most successful of all prostheses of the nervous system. Cochlear implants can provide good discrimination of speech and environmental sounds and some discrimination of music. Knowledge about the optimal time of implantation in children (sensitive periods) has improved the results of cochlear implants in children. Cochlear implants are used in individuals who are deaf or have severe hearing loss caused by loss of cochlear hair cells. Auditory brainstem implants (ABIs) provide stimulation of the cochlear nucleus and are used in individuals whose auditory nerves do not function. Until recently, ABIs were almost exclusively used in adults who had been operated on to remove bilateral vestibular schwannoma because of neurofibromatosis type 2. Used in such patients, ABIs have been less successful than cochlear implants in providing good speech discrimination. However, recently ABIs have been used in patients with other causes of auditory nerve dysfunction and in patients with deformed cochlea in whom it is not possible to perform cochlear implantation. In such individuals and in patients who have had their auditory nerve transected through head trauma and in children with congenital auditory nerve disorders (auditory nerve aplasia), ABIs provide similar speech discrimination as cochlear implants used in individuals with hearing loss of cochlear origin. This recent finding will undoubtedly widen the use of ABIs.

Cochlea implants activate the auditory nerve in the cochlea and thereby bypass sensory transduction in the inner hair cells, and more importantly, the complex function of the basilar membrane as a spectrum analyzer as well as that of the outer hair cells that provide automatic gain control. These functions were regarded to be fundamental for hearing. Frequency analysis performed by the basilar membrane was regarded to be the basis for auditory frequency discrimination that plays an important role in discrimination of sounds such as speech sounds.

When cochlear implants were first introduced, it was met with great disbelief that devices that bypassed the complex function of the cochlea could provide any useful hearing. While early cochlear implants using only one electrode did not provide speech discrimination in the way it is normally understood, the modern multielectrode implants can provide good speech discrimination, although multielectrode implants do not replicate the fine spectral analysis that normally occurs in the

cochlea. It was even more surprising that good speech discrimination could be achieved with cochlear implants that only provide information about the spectrum of sounds without coding the temporal information in the sound waves, which has been regarded to be of fundamental importance for speech discrimination.

The book provides the clinical and scientific basis for cochlear and brainstem implants. The function, implementation and use of such prostheses are the topics of individual papers in the book.

The first paper by Roland and Wright discusses surgical aspects of cochlear implants. It describes techniques of inserting the electrode array using different entry points to the cochlea. This paper also discusses implantation in patients with residual hearing. Nadol and Eddington discuss histopatholgical aspects related to cochlear implants. Geers explains the influence of cochlear implants on language development in children and the effect of the age at implantation.

Although cochlear implants have been in practical use for many years, there are many aspects that need to be clarified. One such aspect is the importance of neural plasticity, which is discussed in detail in two papers. Sharma and Dorman discuss the development of the auditory system and the role of expression of neural plasticity in children with cochlear implants, and Kral and Tillein discuss the basic principles of neural plasticity applied to the auditory system and the principles of sensitive periods. These authors explain the critical periods in children for achieving optimal results. Loizou provides a detailed description of processors and the algorithms used in modern cochlear implants using the principle of the channel vocoder.

The next three papers are devoted to ABIs. Fayad and co-authors explain the surgical aspects of ABIs in patients with neurofibromatosis type 2, and Nevison describes methods for intraoperative testing of ABIs. Colletti discusses results of the use of ABIs in patients with other causes of auditory nerve injuries than bilateral vestibular schwannoma.

Two papers concern physiological aspects of cochlear and auditory brainstem implants. Shepherd and McCreery describe the basis for electrical stimulation of neural tissue and Møller discusses the neurophysiologic basis for cochlear and brainstem implants.

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