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Outcomes review of modern hearing preservation technique in cochlear implant

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ABSTRACT

Introduction: Preservation of residual hearing in cochlear implantation is a main concern for patients and otologists. New electrode arrays as well as development of minimally invasive technique have allowed the expansion of indication criteria for cochlear implantation. The loss of residual low-frequency hearing is thought to be the result of many factors. Opinions differ in regards with the electrodes array characteristics, the surgical implantation technique and the pharmacological therapy used.

Objective: The aim of this research is to analyze the available information pertaining to hearing preservation with cochlear implantation.

Results: Both cochleostomy and round window approaches are adequate, but should rely on the anatomic position of the round window membrane. No electrode design had a higher rate of hearing preservation, either a standard or shorter length was used, or a straight or contoured array. The speed of insertion has a significant impact on hearing preservation and vestibular function. A slow insertion should be used for all cochlear implant insertion, hearing preservation or not. However, the optimal speed of insertion is still unclear. Moreover, the use of steroids regardless of the route or the timing, along with intraoperative topical steroids, had a positive impact on hearing preservation.

Conclusion: Classic atraumatic insertion maneuvers, very slow and delicate insertion and the use of intraoperative corticosteroids improve hearing outcomes. Whichever the surgeon's preferences, all surgical modifications are aimed at the same goal: protection of the delicate intracochlear structures with preservation of residual low-frequency hearing to improve speech perception abilities.

1. Introduction

Emergence of new electrode arrays of different lengths and diameters as well as development of minimally invasive cochleostomy techniques has made possible the option of hearing preservation and the use of a combination of electric (high frequency) and acoustical (low frequency) stimulation of viable auditory nerves for improved hearing performance.

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Electroacoustic stimulation promotes improved recognizing speech in noise, better sound quality and appreciation of music as well as constant sound awareness [1,2].

In order for electroacoustic stimulation to work, residual low-frequency hearing must be first preserved during electrode insertion. The loss of residual low-frequency hearing is thought to be the result of many factors including the technique used to access the scala tympani and the characteristic of the electrode array. Trauma to neuronal cells during surgery leads to neural degeneration, apoptosis, and subsequently loss of function [3]. Opinions differ in regard to electrode array characteristics (depth of insertion, length, diameter, stiffness), the surgical implantation technique (cochleostomy versus round window approach) and the pharmacological therapy used in the perioperative period. This review will examine the data behind each issue.

2. Electrodes selection

2.1. Shorter electrodes

There is no consensus of the optimum insertion depth or electrode length for hearing preservation surgery. Adunka demonstrated that intracochlear trauma increases with depth insertion, resulting from the driving force necessary to push the electrode forward beyond 18–20 mm [4,5]. The distance of 20 mm from the round window corresponds to frequencies near 1000 Hz and should be sufficient to enable electroacoustic stimulation [6,7]. Working on the hypothesis that electrode insertion beyond 20 mm may endanger the basilar membrane stability, shorter electrodes as well as smaller diameter electrodes were developed. Modified more flexible electrode tips were also created to allow a deeper, less traumatic insertion.

Specific electrodes were developed by Med-El Corporation (Flex24, Flex 20 EAS) and Cochlear Corporation (Hybrid L24). The Flex24 electrode is 24 mm long, with an ideal insertion of 360° from the basal turn of the cochlea. It can be inserted via a cochleostomy or a round window technique. To enable more flexibility at the tip, the five most apical electrode contacts are single, whereas the basal seven electrodes are paired. This reduces the diameter of the tip to 70% of the standard Med-El Combi40+ electrode. Reports demonstrated that when using an appropriate atraumatic surgical technique, this highly flexible electrode array produces no substantial trauma to the cochlear structures [5]. Furthermore, in a meta-analysis by Causon, the Med-El Flex24, the shortest electrode included in their study, was reported to have the best median low-frequency hearing preservation score [8]. The least effective hearing preservation was observed with the modiolus approximating Cochlear Contour Advance electrode.

The Hybrid L24 electrode is 16 mm long, with an ideal insertion of 250° from the basal turn of the cochlea. Because it contains 22 electrodes, it can be used as a traditional implant device. With the Hybrid L24, Lenarz reported hearing preservation rates of 88% in the 66 implanted patients, with improved speech recognition compared to the cochlear implant patients without acoustic stimulation [9].

Intracochlear neuronal damage may be early or late in onset. The early-onset damage is caused by the immediate mechanical trauma of insertion to the basilar membrane or stria vascularis. The late-onset damage is hypothesized to be due to chronic inflammatory reaction changes in the cochlea, fibrous encapsulation of the electrode, and scala tympani neo-ossification [4,10,11].

Preservation of residual hearing is a main concern for patients and otologists. However, the possible impact of residual hearing loss (early or late-onset) should be taken into account. While shorter electrodes may have better rates of early hearing preservation, complete electrical stimulation of the cochlea might not be possible in case of late-onset hearing loss. Friedmann reported a significantly better speech understanding following the loss of residual hearing in patients implanted with CI422 compared to patients implanted with the shorter Hybrid-L electrode [12].

2.2. Standard length electrodes

Hearing preservation with full insertion of a standard length electrode is also possible. The advantage of using standard electrodes is the possibility to stimulate the distal cochlea if the hearing loss progresses after implantation. Kiefer showed low-frequency hearing preservation using a limited insertion of the Med-El Combi40+ electrode with a "soft surgery" cochleostomy technique [13]. Instead of inserting the 14 patients with the usual 31.5 mm, the length of insertion was intentionally limited to 19 to 24 mm, to prevent damage to low-frequency regions of the cochlea. Hearing was preserved in 86% of patients (less than 20 dB drop in thresholds).

Another standard length electrode suitable for hearing preservation is the Nucleus CI422. The Nucleus CI422 is 25 mm long, and its straight and slim shape was designed to minimize damage to intracochlear structures during insertion, via the round window technique. This electrode can be fully or partially (20 mm, corresponding to an insertion depth of 360°) inserted. Skarzynski partially inserted (between 20 and 23 mm) the Nucleus CI422 electrode in 23 bilaterally hearing impaired adults. Overall, patients had improved speech recognition in quiet and in noise, with substantially preserved hearing [14]. In a meta-analysis published by Santa Maria, no electrode design demonstrated a clear advantage in hearing preservation [15].

2.3. Cochleostomy technique

Soft surgery or atraumatic insertion principles include no perilymph suctioning, careful manipulation around the labyrinthine opening, very slow and delicate insertion and the use of intraoperative corticosteroids to reduce foreign body reaction. Hearing preservation has been reported in up to 90% of patients [13,16]. The authors also recommend the use of systemic postoperative corticotherapy to reduce postoperative inflammatory response. Antibiotic prophylaxis may prevent the formation of bacterial biofilms at the surface of the electrode, which may lead to acute or chronic labyrinthitis [13].

Lehnhardt first described the "soft surgery" cochleostomy approach in 1993 (minimal cochleostomy inferior and anterior