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Invited Review

Electrode Designs for Protection of the Delicate Cochlear Structures

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The most recent electrode introductions from Advanced Bionics, the HiFocus™ Mid-Scala and the HiFocus SlimJ arrays, have common design goals intended to provide sufficient access to the necessary frequency range while avoiding intracochlear trauma. The electrode choice, either a pre-curved (mid-scala) array or straight (lateral) array, can be made by the surgeon based on anatomical considerations and/or their preferred surgical approach. Both arrays offer ease of handling, suitability for a round window and cochleostomy based insertion and control of the insertion speed.

KEYWORDS: Cochlear implant, electrode, HiFocus, Mid-Scala, SlimJ, pre-curved

INTRODUCTION

The most recent electrodes introduced by Advanced Bionics, the HiFocus™ Mid-Scala and the HiFocus SlimJ arrays (Advanced Bionics AG, Stäfa, Switzerland), have common design goals intended to provide sufficient access to the necessary frequency range while avoiding intracochlear trauma. The electrode choice, either a pre-curved (mid-scala) array or straight (lateral) array, can be made by surgeons based on anatomical considerations and/or their preferred surgical approach. Both of these arrays offer ease of handling, suitability for a round window- or cochleostomy-based insertion, and control of the insertion speed.

Electrode Design Goals

The design and development of the HiFocus Mid-Scala and HiFocus SlimJ electrodes has been documented in the company White Papers [1,2] and includes their histological assessment. HiFocus Mid-Scala has been designed to sit close to, but not against, the medial wall (Figure 1), whereas HiFocus SlimJ is placed closer to the lateral wall (Figure 2). Both electrodes are available on the HiRes™ Ultra 3D Cochlear Implant (Advanced Bionics AG, Stäfa, Switzerland), with an innovative magnet designed for hassle-free magnetic resonance imaging.

The design features of the electrodes are shown in Figures 3 and 4. The tip feature of both the electrodes is intended to aid insertion through the round window. Blue markers on the electrodes guide the surgeon with the suggested insertion technique. The pre-curved HiFocus Mid-Scala electrode has a straight apical portion of the array to reduce the risk of tip fold-over during insertion that may be seen with a peri-modiolar design [3, 4].

The designs of both HiFocus Mid-Scala and SlimJ electrodes have demonstrated excellent preservation of the delicate cochlear structures and consistent placement (Figures 5 and 6).

Asymmetric stiffness to limit the vertical movement of the array in the scala tympani is a prominent feature of the design of both the electrodes. These features, together with a reduced profile, have been shown to reduce or eliminate intracochlear trauma [5-8]. Preservation of the cochlear structures is beneficial, even if there is no aidable residual hearing, because less trauma has been shown to provide better electrical-only hearing [9].

An angular insertion depth of 420° as measured from the round window was chosen for the designs based on the corresponding tonotopic spiral ganglion location [10] that is sufficient to access the frequency ranges necessary for high-level speech recognition without increasing the risk of trauma or perceptual distortions reported with deeper insertions [11-13]. Microanatomical examina-

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Figure 1. HiFocus Mid-Scala electrode.

Figure 2. HiFocus SlimJ electrode.

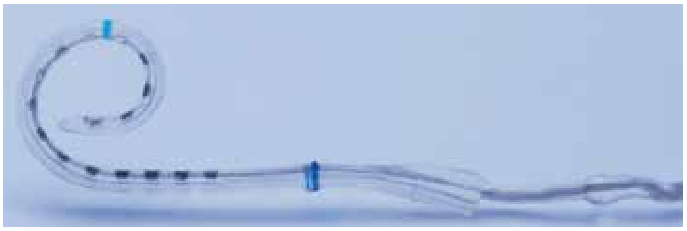

Figure 3. HiFocus Mid-Scala electrode showing the pre-curved shape to conform to the cochlea. It is straightened using a stylet that is removed during insertion.

tion of the temporal bones using micro-computed tomography (CT) [14] has revealed that the dimensions of the scala tympani markedly reduce after 450°. A more consistent insertion depth may result in a greater efficiency in establishing sound processor fitting parameters and improved overall performance [15] and may reduce the time required for adaptation and learning after device fitting [16].

In temporal bone studies [1, 2], the HiFocus Mid-Scala electrode has demonstrated an average angular insertion depth of 420°, with a standard deviation (SD) of 21°, and the HiFocus SlimJ electrode an average angular insertion depth of 413° with an SD of 42°. Larger variability in the depth of insertion has been reported for other electrode designs [17-22], both lateral wall and peri-modiolar.

Figure 4. HiFocus SlimJ electrode has a gentle curvature to ensure movement of the electrode in the apical direction during insertion. The proximal wing feature allows easy handling and insertion.

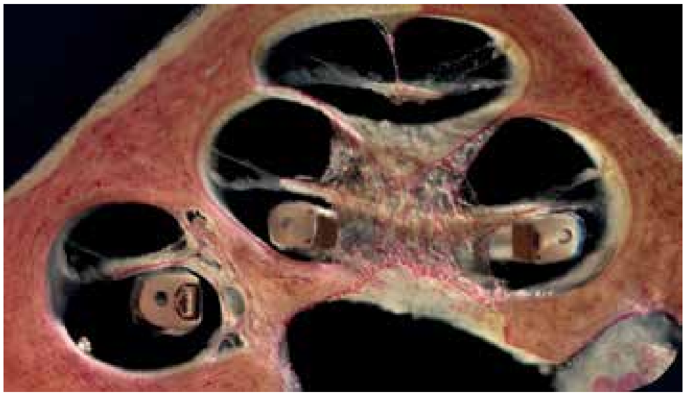

Figure 5. HiFocus Mid-Scala electrode placement in the scala tympani adjacent to the medial wall and away from the cochlear structures.

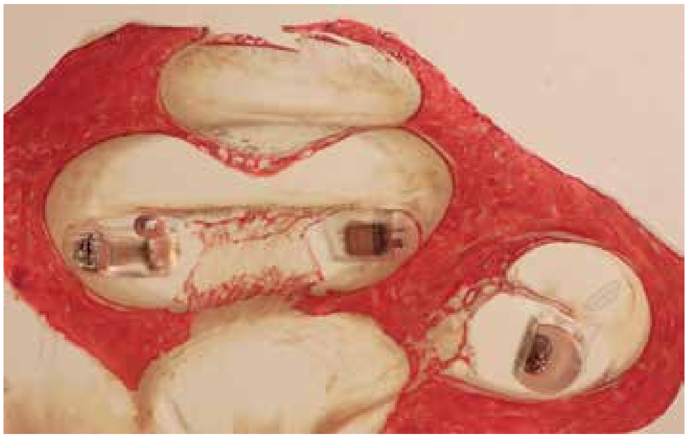

Figure 6. HiFocus SlimJ electrode placement in the scala tympani toward the lateral wall and away from the cochlear structures.

Both electrode designs are capable of providing a controlled insertion, and this has been shown to be beneficial [23].

Real-Time Monitoring During Electrode Insertion

A promising new area of exploration in the field of cochlear implants is the use of real-time electrocochleography (ECochG) recording during electrode insertion to monitor potentials in the cochlea. It has been reported that this real-time monitoring may provide feedback that can improve surgical technique and hearing preservation [24, 25]. The Advanced Bionics ECochG research system (Advanced Bionics AG, Stäfa, Switzerland) can make these measurements with both the HiFocus Mid-Scala and the HiFocus SlimJ electrodes and has been used extensively to conduct research on real-time ECochG [25-27]. This research continues to grow and more firmly indicate that real-time ECochG is an important tool for cochlear implant surgery and should be used in combination with electrodes, e.g., HiFocus Mid-Scala and the HiFocus SlimJ, that have been successfully designed for atraumatic insertion.

CONCLUSION

Modern electrode designs, either pre-curved or straight arrays, can offer sufficient cochlear coverage while avoiding the risk of damage to the delicate cochlear structures. The real-time monitoring of cochlear potentials during insertion will lead to better patient outcomes with current electrode designs and may influence electrode designs of the future.

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