Peri-modiolar electrode arrays: a comparison of electrode position in the human temporal bone


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SUMMARY

This paper describes a radiologic evaluation of three types of peri-modiolar arrays, comparing their trajectory within the scala tympani with a standard Mini-22 electrode. All peri-modiolar arrays were found to lie closer to the modiolus for much of their insertion length compared with the standard array. While one design showed evidence for the potential of increased insertion trauma, two designs produced satisfactory results. Although further electrode development, temporal bone and histopathologic studies are required, it would appear that the benefits of peri-modiolar electrode arrays will be realised clinically.

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INTRODUCTION

While it has been shown that the straight but flexible banded electrode array can be safely inserted into the scala tympani of the human cochlea, histologic and radiologic studies have revealed that the array lies along the outer wall (Shepherd et al, 1985; Clifford and Gibson, 1987; Kennedy, 1987; Cohen et al, in press). Since a profound-total hearing loss is generally associated with a moderate to complete degeneration of the spiral ganglion peripheral process (Nadol, 1990), these electrodes lie some distance from their target neural population - the spiral ganglion sana - located within Rosenthal's canal. Electrophysiologic data have shown that moving the array from the outer wall to a site close to the modiolus results in a significant reduction in threshold and an increase in dynamic range (Shepherd et al, 1985; Clifford and Gibson, 1987). These findings imply that peri-modiolar electrode arrays will produce more localized neural excitation patterns, which should result in an increase in the number of discriminable electrodes, and lead to further improvements in speech perception. An investigation of a prototype peri-modiolar electrode array showed that it could be readily inserted and was located close to the modiolus (Xu et al, 1993). In the present temporal bone study we have used radiologic techniques to evaluate electrode position within the scala tympani of three peri-modiolar electrode designs, and have compared these results with that of a standard Mini-22 electrode array.

Table 1: Description of the four electrode designs used in the present study.

<table>
<thead>
<tr>
<th>Array ID</th>
<th>Design description</th>
<th>% of arrays evaluated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Array #1</td>
<td>Standard Mini-22 electrode array.</td>
<td>1</td>
</tr>
<tr>
<td>Array #2</td>
<td>Precurved electrode array with introducer.</td>
<td>2</td>
</tr>
<tr>
<td>Array #3</td>
<td>Precurved electrode array with polyvinyl alcohol (PVA).</td>
<td>2</td>
</tr>
<tr>
<td>Array #4</td>
<td>Standard array with teflon ribbon.</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 1

Examples of the four electrode designs used in the present study, illustrating their relative position within the human scala tympani. Mean inner and outer scala tympani wall (dotted lines) and round window (dot; N=11), as well as the mean position of the conventional banded electrode array for 28 patients (dashed line) are from Cohen et al, (in press). Note the buckling of both the conventional array and the teflon ribbon of array #4 in the lower basal turn of their respective cochleae (arrow).
RESULTS AND CONCLUSIONS

All eight electrode arrays evaluated in the present study were inserted without undue difficulty. Representative examples of the cochlear position for each of the four types of arrays used are illustrated in Fig. 1.

The standard array accurately followed the mean insertion trajectory recorded for 28 patients (dashed line; Fig. 1); essentially lying along the outer wall of the scala tympani within the upper basal turn (UBT). This electrode was inserted to a depth of 355°. Buckling close to the cochleostomy, which was reported during the insertion, is clearly evident in the lower basal turn (LBT; arrow, Fig. 1), and may have resulted in localized trauma in that region of the cochlea. This type of trauma occurs when the array is inserted past the point of first resistance, and is a result of the increased force required to overcome friction produced as electrodes contact the outer scala tympani wall.

All peri-modiolar electrodes exhibited trajectories that were generally much closer to the modiolus compared with the standard electrode array. Both precurved arrays inserted with the introducer (#2) required larger cochleostomies than that used for the standard array (<1 mm dia). This increased exposure was required to allow the insertion of the introducer into the LBT. Trajectories of both arrays showed that these electrodes were positioned relatively close to the modiolus in both the LBT and lower middle turn (LMT), however, from ~9-14 mm from the round window the trajectory of both arrays approached the outer wall. The mean insertion depth for this electrode design was 374.5° (SD=12; n=2). Array #3, the precurved electrode straightened for insertion using PVA, exhibited quite a different trajectory. Both electrodes exhibited a close modiolar position along almost their entire length except for the first 3-4 mm from the cochleostomy (Fig. 1). The mean insertion depth for this electrode design was 395° (SD=12, n=2). The insertion of this array required care to ensure that it was correctly oriented to resume a curvature consistent with that of the cochlea. Array #4, the standard electrode with a teflon ribbon fixed to its tip, exhibited what appeared to be relatively close alignment with the modiolus for two of the three electrodes evaluated. The third array showed only a marginally improved trajectory compared with the standard array in the UBT. One feature of this design was the close alignment of the tip of the electrodes to the modiolus. The mean insertion distance for this design was only 344° (SD=24.6, n=3). In all three cases the teflon ribbon, used to displace the electrode array towards the modiolus, showed clear evidence of buckling. While histological analysis of the subsequent damage is required, it is reasonable to suspect this would result in trauma to surrounding cochlear structures. Moreover, for all three temporal bones the teflon ribbon appeared to be outside the outer scala tympani wall for much of its trajectory. This may indicate that the ribbon had torn the spiral ligament and was resting along the otic capsule within the scala media. Finally, as with array #2, this design was inserted using an insertion tool. It was noted that this procedure reduced the surgeon's ability to precisely determine the extent of insertion resistance.

REFERENCES


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Title:
Peri-modiolar electrode arrays: a comparison of electrode position in the human temporal bone

Date:
1997

Citation:

Persistent Link:
http://hdl.handle.net/11343/27011

File Description:
Peri-modiolar electrode arrays: a comparison of electrode position in the human temporal bone

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