Electrophysiological Insertion Properties in the Gerbil Using a Flexible Array

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Background: Hearing preservation during cochlear implantation has become progressively more important. Specifically, non-traumatic electrode insertions might help to facilitate preservation and subsequent electrophysiological and tonotopic mapping (EAS or Hybrid stimulation). However, the mechanisms of hearing loss during cochlear implantation remain unknown. In an effort to improve our understanding and the outcomes of hearing preservation during cochlear implantation, we have developed an animal model. The model allows us to record early auditory potentials during electrode insertions and thus correlate electrophysiological and mechanical findings. Previously, we demonstrated our ability to detect cochlear trauma using a rigid electrode. However, current surgery features flexible electrodes and in an effort to simulate this, we have developed a flexible array suitable for implantation in the gerbil.

Aims: To evaluate our animal model of hearing preservation cochlear implantation and our ability to detect intracochlear trauma using a flexible electrode carrier in the gerbil.

Table 1: Summary of flexible electrode insertions

<table>
<thead>
<tr>
<th>Histological Damage</th>
<th>Electrode Type</th>
<th>Time (min)</th>
<th>Early</th>
<th>Late</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support Cell Damage</td>
<td>No</td>
<td>0.00</td>
<td>R</td>
<td>N/A</td>
</tr>
<tr>
<td>Support Cell Damage</td>
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<td>N/A</td>
<td>R/N</td>
</tr>
<tr>
<td>Hole</td>
<td>No</td>
<td>0.00</td>
<td>R</td>
<td>N/A</td>
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<td>R/N</td>
</tr>
<tr>
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<tr>
<td>125</td>
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<tr>
<td>126</td>
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Table 2: Summary of rigid electrode insertions

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<th>Electrode Type</th>
<th>Time (min)</th>
<th>Early</th>
<th>Late</th>
</tr>
</thead>
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<td>R/N</td>
<td>N/A</td>
</tr>
<tr>
<td>Support Cell Damage</td>
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<tr>
<td>Hole</td>
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<tr>
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<tr>
<td>122</td>
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<td>126</td>
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</table>

Materials and Methods:

Animal models:
- Rats, m/v (males, 200 g; good low-frequency hearing, easy access to cochlea)

All animals were anesthetized according to the standard described by the National Institutes of Health National Center for Com and the Laboratory Animal Model Program, using protocols approved by the Institutional Animal Care and Use Committee (AACUC) of the study institution.

Preparation of animal cochlear structures:
- Deep urethane anesthesia (2.5% solution in saline, 1.5 g/kg i.p.)
- In a double walled sound attenuated booth
- Core body temperature monitored with a rectal probe

Surgical procedure:
- Bony bulla exposed via a standard postauricular approach
- Removal of pericranium for consistent sound delivery
- Identification of structures of the bulla and round window
- Small slit was made through the round window
- Placement of microelectrode recording electrode position and placed onto the membrane

Acoustic Stimulation & Calibration:
- Stimuli: 1, 2, 4, 8, and 16 kHz tone bursts at 60 dB SPL
- at varying SPL, for all responses to be similar to the 1 kHz at 60 dB SPL
- 10 ms plateau and 2 ms rise/fall times and a 30 ms interval
- Well shielded loudspeaker (Beyer DT-48 custom software, National Instruments input/output board (model 6525E), and a Tucker-Davis system (headphone buffer, model HD4B).

The animal was awake for the acoustic tympanic membrane.

Calibration was performed using a 25 kHz signal.

Electrode & Recording Configuration:

Two different electrodes were used:
- Flexible: 200 μm diameter flexible Teflon-insulated tungsten tip with a 10 μm tip.
- Rigid: 40 μm diameter rigid Teflon-insulated tungsten tip with a 5 μm tip.

Results with Flexible Electrode Insertions:
- A case that illustrates several types of response change is shown in Figs. 1 and 2 (see legend)
- Changes in CM and CAP magnitudes at a single intensity were measured during insertion
- Variations of the CM and CAP patterns were noted during insertions

Results with Rigid Electrode Insertions:
- A representative example is shown in Fig. 4 (see legend for details)
- CM at each frequency demonstrates relatively large changes, while the CAP was more stable
- No rigid electrode specimen showed a tonotopically ordered decline in response with insertion depth
- No sound jumps in the CM at 16 kHz or any other frequency

Discussion & Conclusions:
- These results demonstrate the feasibility of recording meaningful physiological responses with flexible electrode insertions and to draw conclusions on mechanical interactions of the electrode with cochlear structures
- Observed response changes due to electrode travel through the basal turn were complex
- Each case demonstrated unique features, however, general trends were clearly present and can be used to understand the physiological responses and interactions
- The physiological changes were consistent with modes of travel where there was no contact with damage to the auditory apparatus, and where contact and possible damage were occurring
- The physiological changes associated with the damage mode in many cases correlated with particular anatomical damage

One limitation is that these experiments were done on normal-hearing gerbils. Thus, the next step was to perform these experiments in a hearing loss model as described previously

References: