Physiological and histopathological effects of chronic monopolar high rate stimulation on the auditory nerve

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Speech processing strategies based on high rate electrical stimulation have been associated with improvements in speech perception among cochlear implant users. The present study was designed to evaluate the electrophysiological and histopathological effects of long-term intracochlear monopolar stimulation at the maximum stimulus rate of the current Nucleus Cochlear implant system (14493 pulses/s) as part of our ongoing investigations of safety issues associated with cochlear implants.

Six normal hearing cats were bilaterally implanted with a three channel platinum (Pt) scala tympani electrode array and unilaterally stimulated in a monopolar configuration for periods of 600 to 2700 h. A return Pt-electrode was placed outside the bulla. The contralateral cochlea was used as an implanted but unstimulated control. Continuous chronic electrical stimulation at behavioural mid-dynamic range intensities consisted of 25 μs/phase charge-balanced biphasic current pulses delivered at a rate of 4831 pps/channel for ~16 h/day via a transcutaneous leadwire connected to a backpack-stimulator. Stimulus current amplitudes used in the study ranged from 0.55 to 1.35 mA, the stimulus intensity varied from 0.014 to 0.034 μC/phase and charge density from 4.30 to 6.51 $\mu C \cdot cm^{-2}$geom. per phase. The electrodes were shorted between current pulses and the extracochlear electrode capacitively coupled (0.1μF) to minimise direct current (DC). In addition the electrically evoked brainstem response (EABR) was also recorded to ensure that the chronic stimulus was above threshold.

Residual DC levels were negligible (0.0 μA), indicating that the electrode shorting in combination with capacitive coupling was very effective at these high stimulus rates. Wave IV of the EABR, evoked via bipolar electrodes and plotted as a function of stimulus current, generally showed little or no increase in threshold over time. Histopathology showed in the majority of cochleae a minimal tissue response in the scala tympani. However, in a few cochleae extensive fibrous tissue growth and new bone formation was noted. No statistically significant difference between spiral ganglion cell densities within corresponding regions of the stimulated and their contralateral implanted, but unstimulated cochleae ($p=0.394$, Mann-Whitney Rank Sum Test) was found. There was also no statistically significant correlation between stimulation time and spiral ganglion cell density ($R = -0.0112$; $p>0.05$, Spearman Rank Order Correlation). However, a negative correlation between implantation time and spiral ganglion cell density ($R = -0.684$; $p=0.0126$) was found.

The stability of both the EABR thresholds and morphology, as well as the spiral ganglion cell statistics indicate that monopolar electrical stimulation at ~5000 pps using charge densities between 4.30 and 6.51 $\mu C \cdot cm^{-2}$geom. per phase does not adversely affect the auditory nerve.

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