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ELECTRICAL STIMULATION OF THE AUDITORY NERVE: EFFECTS OF HIGH STIMULUS RATES
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We have previously described non-damaging stimulus levels for chronic intracochlear electrical stimulation (Shepherd et al., 1983). However, maximum safe stimulus levels have yet to be clearly defined. Moreover, the importance of various stimulus parameters and their effects on the auditory nerve is not well understood. In the present study we have examined the effects of stimulus repetition rate on the auditory nerve by monitoring the Electrically-evoked Auditory Brainstem Response (EABR). Such information is necessary if speech processing strategies incorporating high pulse rates (i.e. > 300 pps) are to be made available to cochlear implant patients.

Normal hearing and neomycin deafened cats were anaesthetized and implanted with bipolar scala tympani electrodes. The animals were stimulated continuously for periods of up to 12 hours at defined stimulus intensities and stimulus repetition rates. Electrical stimuli consisted of charge balanced biphasic constant current pulses. EABRs were recorded prior, during and periodically following completion of the stimulus regime. Threshold, latency and EABR input-output functions (stimulus current versus amplitude of the evoked response) were determined from wave IV (latency 2.6-3.2 ms).

Continuous stimulation at moderate stimulus intensities (0.8-1.0 mA; 200 μs/phase) at a rate of 100 pps for periods of up to 12 hours, produced minimal changes in the EABR. Stimulation at progressively higher stimulus rates (200, 400, 800 and 1600 pps) produced progressively greater reductions in the post-stimulus input-output function. Post-stimulus recovery to pre-stimulus levels was rapid following stimulation at 200 pps (typically less than 90 seconds). Post-stimulus recovery time increased with stimulus rate. At high stimulus rates (800 and 1600 pps) post-stimulus recovery was incomplete. In cases where post-stimulus recovery was rapid a temporary 'sensitization' period was frequently observed. During this period the amplitude of the evoked potential was larger than the pre-stimulus response for the same stimulus level. This 'sensitization' period typically lasted 20 minutes. These temporary stimulus induced changes in input-output functions were also reflected in latency and threshold data. Continuous stimulation at higher stimulus intensities (1.8 mA; 200 μs/phase - significantly higher stimulus levels than are used clinically), produced significant temporary changes in the EABR at 100 and 200 pps. At higher stimulus rates (400 pps) permanent reductions in the EABR input-output functions were recorded. Both normal hearing and neomycin deafened animals showed similar stimulus induced changes in EABR.

The present results indicate that high electrical stimulus rates can result in significant reductions in the evoked auditory brainstem response. Moreover, these stimulus induced changes are more significant at higher stimulus intensities. Significant reductions in perceptual loudness have also been described psychophysically in cochlear implant patients electrically stimulated using a 300 Hz sinusoidal waveform (Shannon, 1983). These findings have some important practical implications for the design of speech processing strategies based on high stimulus rates.

The mechanisms underlying these stimulus induced changes are probably due to adaptation and more long-term metabolic changes. It would appear that attempts to stimulate auditory nerve fibres with highly synchronous stimuli such as an electric pulse, at unnaturally high stimulus rates, places considerable metabolic stress on the target neural population. The effects of other stimulus parameters including total charge injected, remains to be determined.