Effects of Age on the Preservation of Residual Hearing with Cochlear Implants

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Summary

Chronic cochlear implant (CI) use results in a significant loss of residual acoustic hearing in some, **but not all**, animals. The loss occurs more rapidly in animals deafened as adults than those deafened as neonates.

Introduction

Cochlear implant (CI) recipients with residual hearing in their implanted ear receive both electric and acoustic stimulation (EAS). These EAS patients have improved speech perception, particularly in the presence of background noise, that is dependent on their residual hearing. Optimal hearing preservation is therefore a major factor in achieving the best possible auditory experience for these EAS patients. However, a small but significant number of EAS patients lose their residual hearing following implantation, although the mechanism(s) of these losses are not clear.

Method

To determine the effects of age at implantation on the preservation of residual hearing, this study evaluated hearing preservation, using auditory brainstem response recordings (ABRs) and auditory nerve compound action potential recordings (CAPs), in both neonatal and adult onset partially deaf cats. Neonatal cats (n=8) were deafened with a single administration of kanamycin sulfate (KA) subcutaneously at 200 mg/kg, followed by an intravenous infusion of ethacrynic acid at 25 mg/kg 5 days after birth[1]. Adult cats (n=3) were deafened with daily subcutaneous injections of KA (200 mg/kg) for up to 30 days[2]. After stabilization of the hearing loss (2 months for neonates, 6 months for adults), all animals were implanted with a Hybrid-L 14 electrode array[3]. One month later, chronic intracochlear electrical stimulation (ES) from a clinical CI and speech processor[4] commenced and continued for 5 months. ABRs and CAPs were recorded at 'switch-on', 'mid-way' through the chronic ES, and at the completion of the chronic ES (Figure 1).

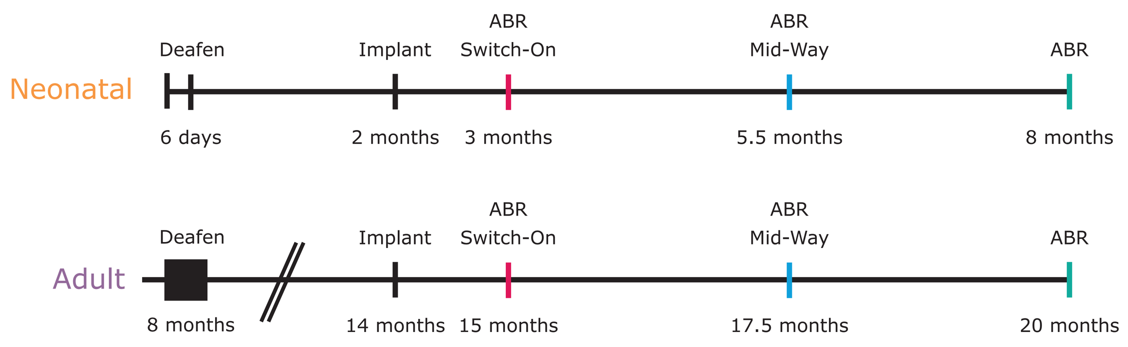


Figure 1. Timeline of the deafening, implantation, stimulation and data collection points used. Switch-On = Commencement of chronic ES.

Results

All animals had measurable hearing in the low- to mid-frequency range (below 4-8 kHz, apical to the intra-cochlear electrode array) throughout the experiment. As illustrated in Figure 2, some animals did not lose any hearing over the 5 month chronic stimulation period. However, for other animals (Figures 3 & 4) there were frequency specific increases in threshold of approximately 30 dB.

Figure 2. Representative CAPs to 2 kHz tone-pips (5 ms duration, 1 ms rise/fall) from a neonatally deafened animal at switch-on, mid-way through, and completion of the 5 month chronic stimulation period. The CAP audiogram (right panel) shows that there was no substantial hearing loss for this animal.

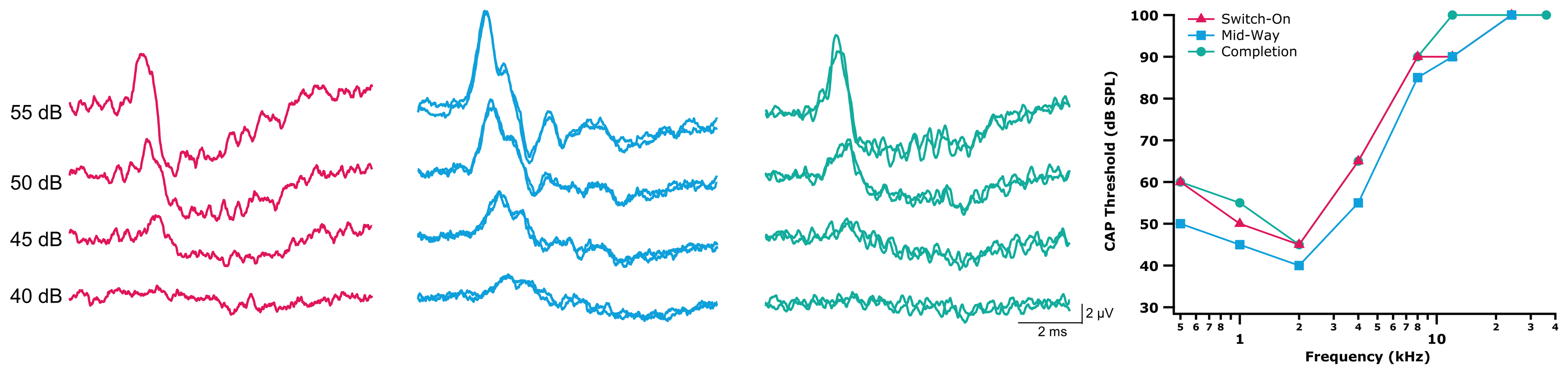
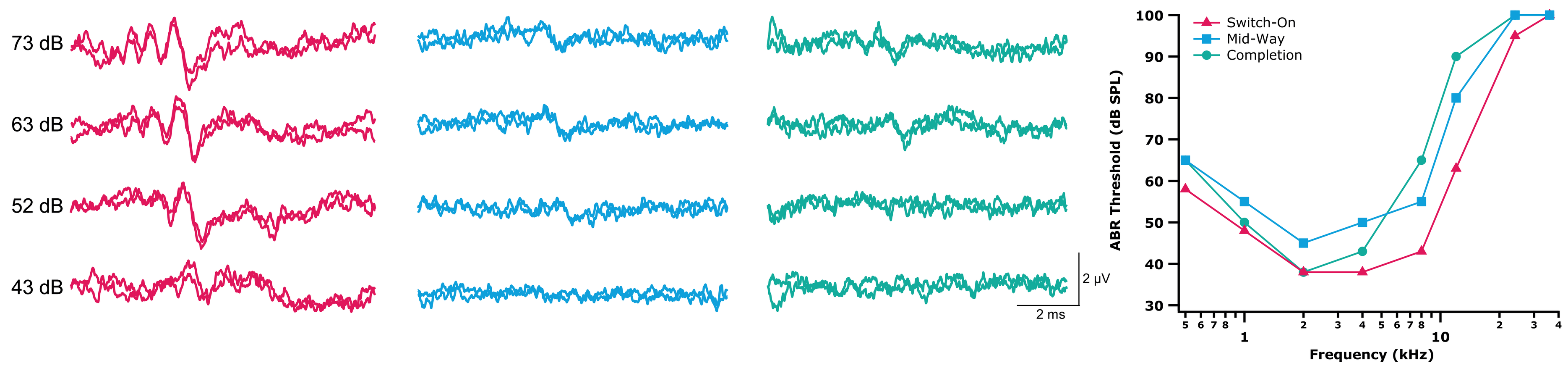


Figure 3. Representative ABRs to 8 kHz tone-pips (5 ms duration, 1 ms rise/fall) from an animal deafened as an adult at switch-on, mid-way through, and completion of the 5 month chronic stimulation period. For this animal, the 8 kHz threshold increased from 43 to 63 dB SPL over the stimulation period. The ABR audiogram (right panel) shows the loss of hearing was restricted to 8 kHz and above for this animal.



The neonatally deafened animals did not exhibit a significant hearing loss during the first half of the chronic stimulation period (paired t-test, p-values > 0.35; Figure 5), but did during the second half (p-values < 0.001). In contrast, the animals deafened as adults exhibited a sustained loss of hearing throughout the entire chronic stimulation period.

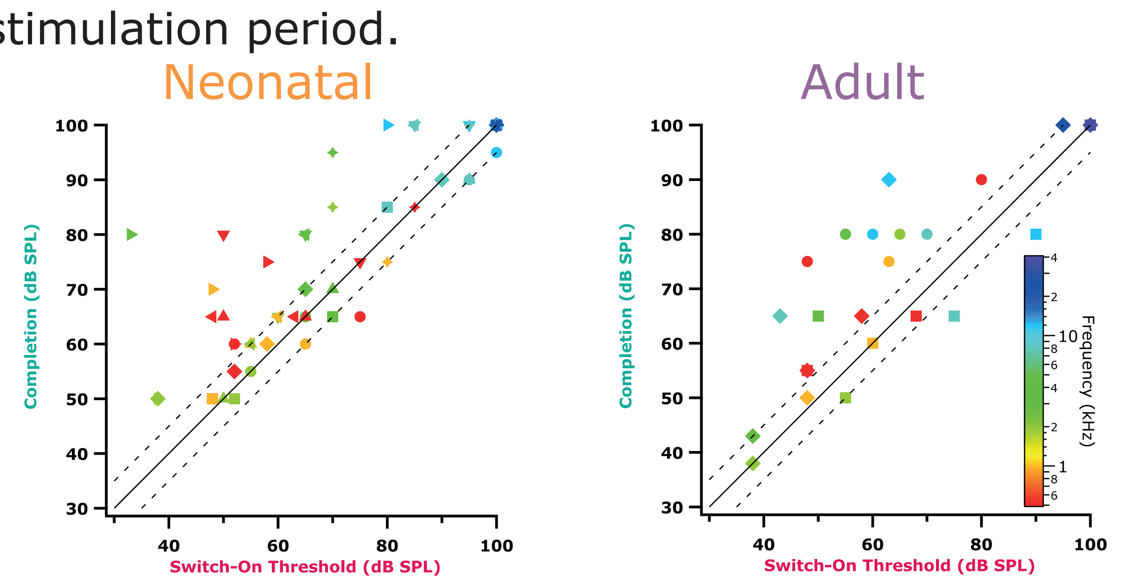


Figure 4. Scatter plot of completion vs switch-on ABR thresholds for the neonatal (left) and adult onset (right) groups. Individual animals are represented by different symbols. Points above the solid line represent an increase in threshold over the chronic stimulation period. The dashed line indicates a threshold shift of more than 5 dB.

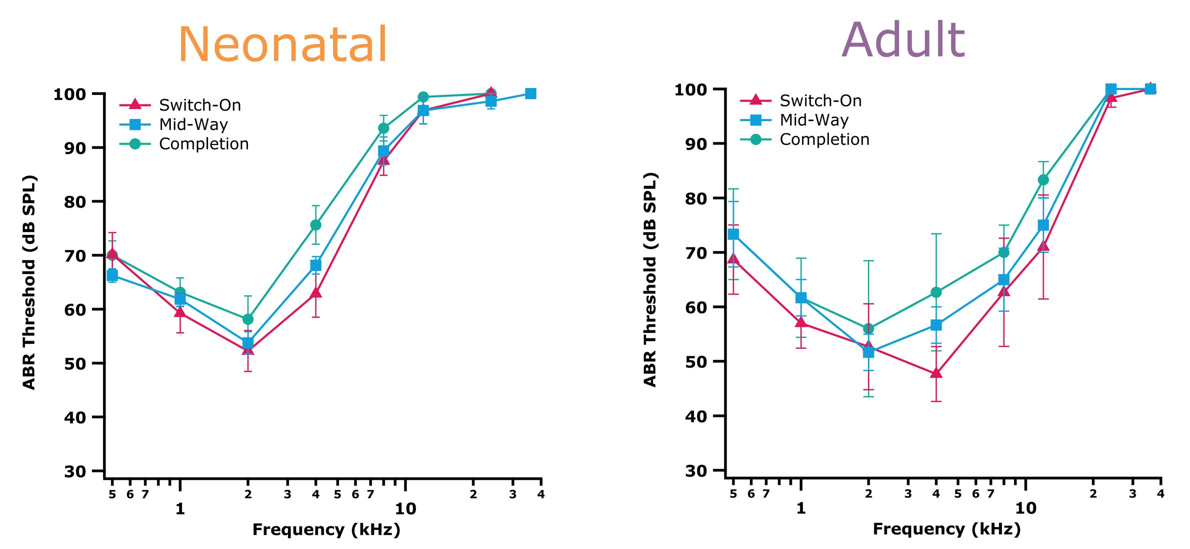


Figure 5. Group mean (± SEM) ABR audiogram at switch-on, mid-way through, and completion of the 5 month chronic stimulation period for the neonatal (left) and adult onsert (right) groups.

Discussion and conclusion

The variability in hearing preservation in our animals mirrors that seen clinically (i.e. some animals exhibited no additional loss of hearing during the chronic stimulation period, while others had a substantial loss). The loss was greatest in regions of the cochlea near the tip of the electrode array. Interestingly, the loss occured more rapidly in animals deafened as adults than those deafened as neonates. Although, this finding is complicated by the slightly different deafening techniques used in the two groups. Histological analysis of the cochleae will provide an indication of the mechanism(s) responsible for the ongoing loss of residual hearing.

References

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Acknowledgments

We wish to acknowledge Ms. A. Neil, N. Critch and A. Morley for technical assistance. This work was funded by NH&MRC and Cochlear LTD. The Bionics Institute acknowledges the support it receives from the Victorian Government through its Operational Infrastructure Support Program.