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ELECTRICAL STIMULATION OF THE AUDITORY NERVE: THE INFLUENCE OF ELECTRODE POSITION ON NEURAL EXCITATION

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Introduction

Improved speech recognition among cochlear implant patients would appear to be dependent on a number of factors including improved speech processing strategies and an improvement in the effectiveness of electrically stimulating residual auditory nerve fibers (*i.e.* lower thresholds, wider dynamic ranges and more localized current spread).

Previous human temporal bone studies have shown that free fit scala tympani electrode

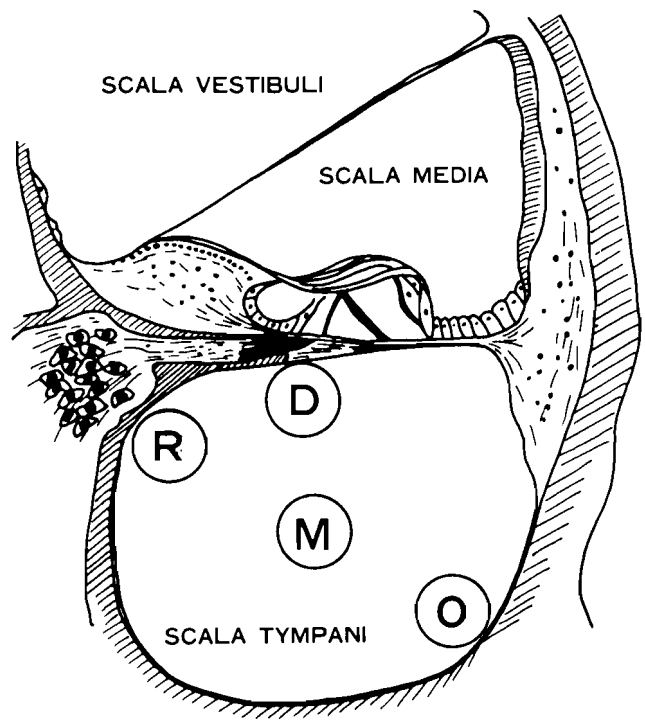


Fig. 1. The electrode array locations within the scala tympani in the present study. O: the outer wall of the scala tympani; M: the middle of the scala tympani; R: adjacent to Rosenthal's canal; D: adjacent to the peripheral dendrites.

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Table 1. Summary of the histopathological results for the 6 cochleas in this study

LB-Lower basal turn, UB-Upper basal, LM-Lower middle, UM-Upper middle, LA-Lower apical, UA-Upper apical.
Insertion trauma, Structure of organ of Corti and Hair cell: - = absent, + = present.

	Cat 488						Cat 493						Cat 494					
	LB	UB	LM	UM	LA	UA	LB	UB	LM	UM	LA	UA	LB	UB	LM	UM	LA	UA
Insertion Trauma	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Organ of Corti	-	-	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+
Hair Cell	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% of Dendrite Survival	75	75	76-99	76-99	100	100	76-99	76-99	100	100	100	100	76-99	76-99	76-99	100	100	100
% of Spiral Ganglion Cell Survival	75	75	76-99	76-99	100	100	76-99	76-99	76-99	76-99	100	100	76-99	76-99	76-99	100	100	100
	Cat 495						Cat 492						Cat 472					
	LB	UB	LM	UM	LA	UA	LB	UB	LM	UM	LA	UA	LB	UB	LM	UM	LA	UA
Insertion Trauma	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Organ of Corti	-	+	+	+	+	+	-	-	-	+	+	+	-	-	+	+	+	+
Hair Cell	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
% of Dendrite Survival	75	76-99	76-99	76-99	100	100	50	50	50	50	51-74	51-74	25	50	51-74	51-74	75	76-99
% of Spiral Ganglion Cell Survival	75	76-99	76-99	76-99	100	100	50	51-74	51-74	51-74	75	76-99	50	51-74	51-74	75	75	75

arrays generally lay along the outer wall of the scala tympani^{1,2}. Therefore, there is a relatively large distance between the electrode array and the residual neural elements within Rosenthal's canal.

In the present study, we systematically varied the location of the electrode within the scala tympani to examine the influence of electrode position on neural excitation.

Materials and methods

Electrically evoked auditory brainstem responses (EABRs) were recorded from six chronic kanamycin deafened cats. EABRs were evoked via bipolar stimulation, using the Cochlear Pty. Ltd. banded electrode array; EABRs were recorded with the array placed in four locations within the scala tympani: the outer wall (O); middle of the scala (M); adjacent to Rosenthal's canal (R); and adjacent to peripheral dendrites (D) (Fig. 1).

Electrical stimulation was provided by an optically isolated, charge-balanced biphasic current source with a variable current level of less than 2.0 mA, and a pulse width of 0.2 msec/phase. Stimuli were presented at a rate of 33 pulses per second. Each response was amplified and filtered (150 Hz to 3 kHz). Five hundred responses were averaged. EABR thresholds, and amplitudes versus stimulus current (input-output function) were determined for wave IV (approx. 2.5 - 3.0 msec) of the EABR.

On completing the EABR study, each animal was sacrificed for cochlear histopathology.

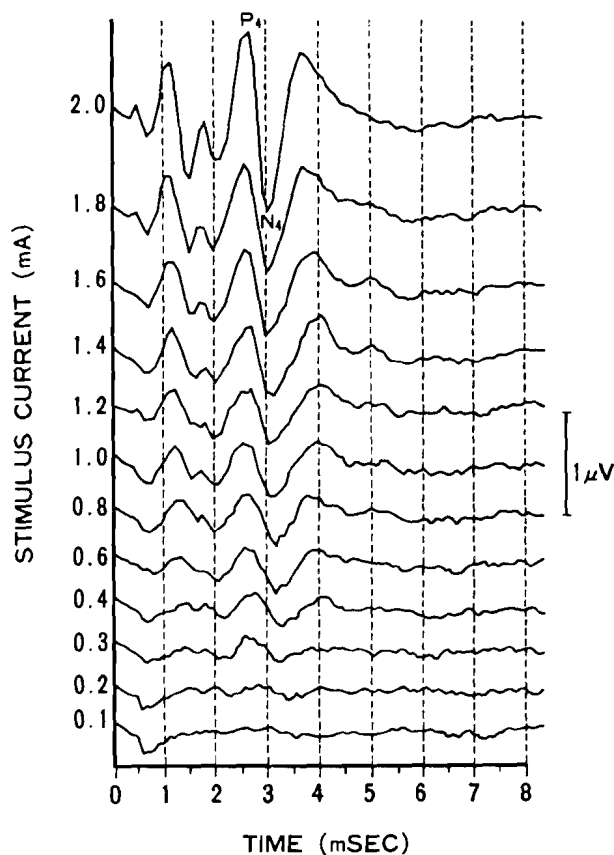


Fig. 2. An example of a set of EABRs for biphasic current pulses of 0.1 to 2.0 mA at 0.2 msec per phase. Growth responses data were obtained by measuring the N4-P4 wave at approx 2.5-3.0 msec. These responses were recorded using stimulus artifact suppression circuitry.

Results

Cochlear histopathology

Table 1 contains a summary of the histopathological results for the six cochleas in this study. Insertion trauma was not observed and hair cells were completely absent in all cochleas. The structure of the organ of Corti was generally absent in the lower cochlear turns, however, was usually evident more apically. The percentage survival of peripheral dendrites and spiral ganglion cells increased towards the cochlear apex.

Auditory brainstem responses

A typical set of EABRs - recorded from a deafened cat - is shown in Fig. 2 for 0.2 msec duration biphasic current pulses varying from 0.1 mA to 2.0 mA. These responses represent a volley of afferent activity along the auditory brainstem following direct electrical excitation of the auditory nerve fibers.

EABR input-output functions for all animals in this study are illustrated in Fig. 3. This figure demonstrates the influence of electrode position on both EABR threshold and supra threshold responses. EABR thresholds were significantly reduced as the electrode array was moved from the outer wall of the scala tympani to a location closer to the neural elements (Dendrites and Rosenthal's canal; Fig. 3). These changes in the location of the stimulating

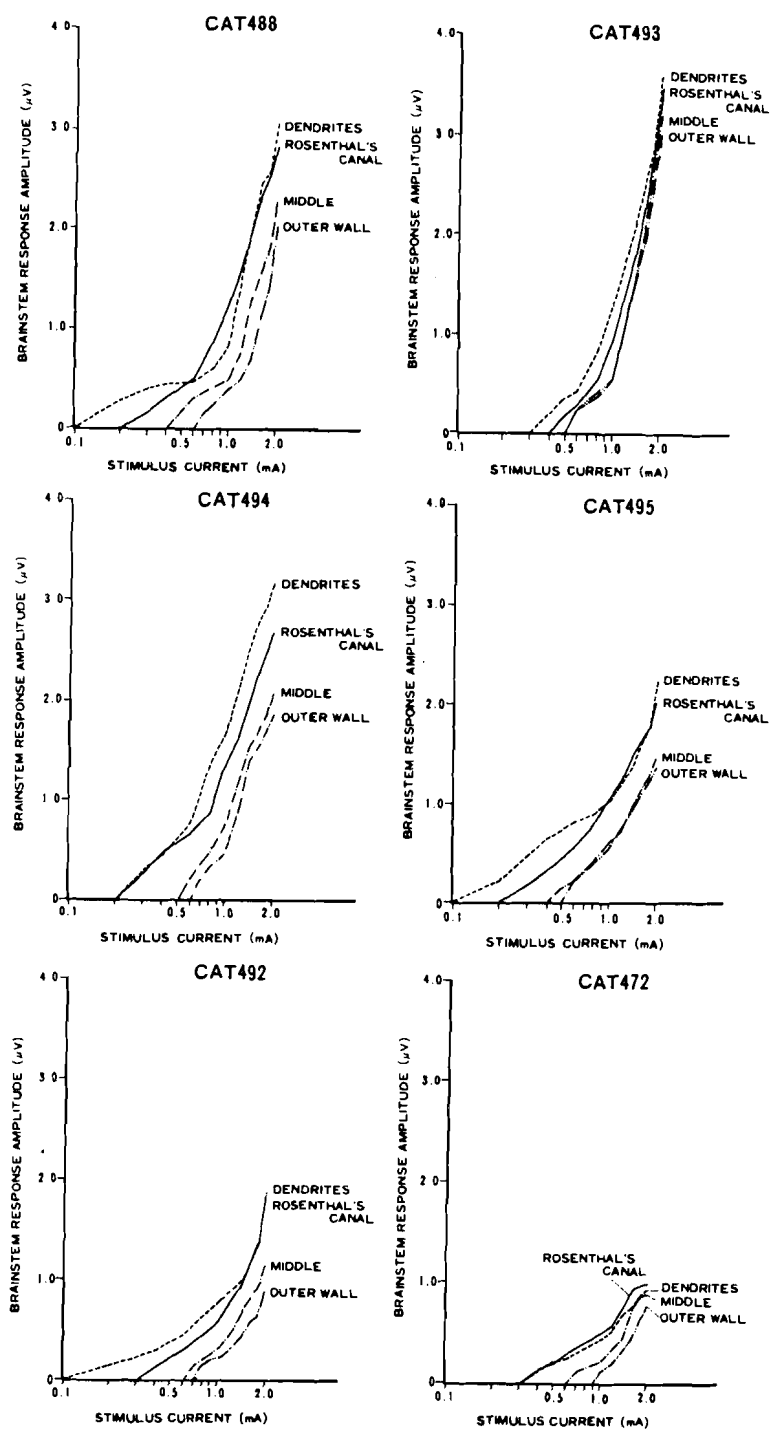


Fig. 3. EABR input-output functions for all chronically deafened cats with four array locations within the scala tympani at bipolar stimulation.

electrode also resulted in a reduction in the gradient of the EABR input-output function and therefore an increase in the effective dynamic range.

Such position dependent changes in the EABR were consistently observed among all animals examined although there were significant variations in the extent of neural histopathology (Table 1).

Discussion

Future improvements in the performance of patients using cochlear implants may depend on repositioning the location of the electrode array within the scala tympani. In the present study, EABR thresholds were significantly reduced and the effective dynamic range increased as the electrode array was positioned closer to the residual nerve fibers. Therefore, it is of importance to consider the position of the electrode array in relation to the neural elements being stimulated.

These results showed that there was little difference in EABR thresholds and dynamic ranges when an array was placed either adjacent to the peripheral dendrites or Rosenthal's canal. This was the case even when the percentage of the peripheral dendrite survival was low (*e.g.* cat 472, Fig. 3). We would expect that such changes in the threshold and the dynamic range of a cochlear implant would be reflected in an improvement in the clinical performance of cochlear implant patients. We consider that the placement of a scala tympani electrode array close to the peripheral dendrites would, in practice, be difficult to achieve while minimizing insertion trauma. From the results of the present study, we feel that the optimum placement of such an electrode array would be close to the modiolus.

Acknowledgements

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