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Medialization of electrode array in cochlear implantation

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Abstract
In the last few years, the main thrust of research into cochlear implantation has centred around the development of advanced multi-channel implants. A new area of development is now concentrating on maximizing the potential of each individual electrode in order to improve the quality of hearing. This study involved the medialization of the cochlear implant electrode array using a silastic positioner in five patients. Two parameters were measured, namely current units needed to produce a stapedial reflex, and impedance levels between the electrode and modiolus. On insertion of the cochlear implant, readings were taken before the insertion of the positioner, immediately afterwards and at two months.

Key words: Cochlear Implants; Electrodes; Surgical Procedures, Elective

Introduction

Battmer *et al.*[1] have shown in their studies that when a cochlear implant is placed closer to the medial wall of the cochlea (modiolus), the current from each electrode array is more focused allowing for increased channel selectivity but at reduced stimulation level.

Clarion® have designed a silastic positioner to medialize the electrode array with the intention of creating better contact with the modiolus and improving the depth of insertion (Figure 5). (A silastic positioner is used to medialize the electrode array of the cochlear implant.) With the electrode closer to the spiral ganglions, it is thought that less current is required for stimulation reducing interaction with other channels.[2] This may allow speech-processing strategies involving simultaneous stimulation of adjacent electrodes to be more effective.

Focused electrical stimulation also reduces the risk of current spread limiting potential side-effects such as facial nerve stimulation.

Patients and methods

Five patients undergoing cochlear implantation were selected to participate in the study from the cochlear implant programme at the North Riding Infirmary, Middlesbrough. The patient's age, sex and cause of hearing loss, are shown in Table I.

A cortical mastoidectomy with posterior tympanotomy was performed and a cochleostomy into the basal turn of the cochlea was fashioned. A Clarion® cochlear implant with eight paired electrodes was inserted and an integrity test was carried out in situ to check the functioning of each electrode. The computer software 'SCLIN '98 for Windows' of the Advanced Bionics company was used to measure two parameters. These are shown below:

1. Current units (c.u.) needed to achieve a stapedial reflex threshold as observed directly through an operating microscope.
2. Impedance measurements measured in kilo-ohms (k.o.).

After placement of the cochlear implant, measurements were taken at channels 3 and 6 before insertion of the electrode positioner and immediately afterwards. This was followed by a series of impedance readings taken at two months.

Results

A power analysis was performed initially to define the number of cases needed to achieve a statistically significant result. The minimum data set produced was found to total at least 25 patients that would require a two-year period to complete the study.

TABLE I
DEMOGRAPHIC SPREAD OF STUDY GROUP

Patient no.	Age	Sex	Cause of hearing loss
1. JA	2	M	CHARGE syndrome
2. DM	65	M	Otosclerosis
3. DS	38	F	Progressive SNHL
4. JB	41	F	Progressive SNHL
5. CW	2	M	Congenital abnormality (unknown cause)

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TABLE II

STAPEDIAL REFLEX THRESHOLDS MEASURED AT CHANNELS 3 AND 6 BEFORE AND IMMEDIATELY AFTER INSERTION OF ELECTRODE POSITIONER

	Channel 3		Channel 6	
Patient no.	Before	After	Before	After
1. JA	241	172	**184**	**190**
2. DM	**136**	**190**	348	275
3. DM	1000	480	1000	530
4. JB	172	136	156	136
5. CW	225	117	250	225

TABLE III

IMPEDANCE LEVELS MEASURED AT CHANNELS 3 AND 6 BEFORE AND IMMEDIATELY AFTER INSERTION OF ELECTRODE POSITIONER

	Channel 3		Channel 6	
Patient no.	Before	After	Before	After
1. JA	9	13	9	25
2. DM	14	22	11	19
3. DM	13	24	15	20
4. JB	**21**	**14**	18	20
5. CW	**25**	**22**	**22**	**18**

Therefore it was decided to present our initial experiences as observations only, with a view to producing a statistically significant paper once a representative patient population had been sampled.

Table II denotes the minimum current needed to produce a stapedial reflex, while Table III shows the impedance readings measured. Both sets of data were recorded from channels 3 and 6 pre- and immediately post-insertion of the electrode positioner.

In Table II, the stapedial reflex thresholds dropped in eight out of the 10 electrodes measured. The two electrodes that showed a rise (shown in bold) were located in separate implants.

Figures 1 and 2 demonstrate graphically the change in the stapedial reflex thresholds as measured in channels 3 and 6 respectively.

In Table III, seven electrode pairs showed the predicted response of an increase in impedance but three electrode pairs (denoted in bold) showed a decrease impedance, two arising from both channels measured in the same implant.

Two months after insertion of the cochlear implant plus positioner, a repeat set of impedance readings were taken (2 m) and compared with the initial impedance results measured immediately after insertion of the electrode positioner (0 m). These measurements are shown in Table IV. Stapedial reflexes were not recorded, as this would require visualization of the stapedial muscle.

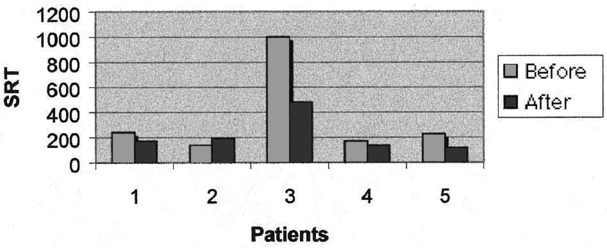

FIG. 1

Stapedial reflex thresholds measured at channel 3 before and immediately after the insertion of the electrode positioner.

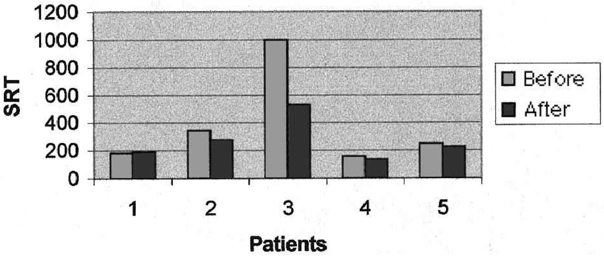

FIG. 2

Stapedial reflex thresholds measured at channel 6 before and immediately after the insertion of the electrode positioner.

All but two of the impedance readings at two months had increased. Those that fell were not only found to be in different implants (denoted in black) but were in implants that showed strong increases in impedance initially. The results that showed an initial fall but rose at two months are denoted with an asterisk. Figures 3 and 4 depict the above results graphically as measured in channel 3 and channel 6 respectively.

Discussion

The use of electricity to stimulate hearing is not a new concept as we know that, in 1800, Alessandro Volta placed 'live' metal rods in his ears causing him to experience a degree of auditory stimulation.[3] Djurno and Eyries achieved limited stimulation of the auditory nerve in 1957, but it was William House in 1961 who implanted the first single electrode implants that have steadily evolved up until the present day.[4]

As implants have become extremely sophisticated, improved methods of electrode array insertion have been developed in order to facilitate the use of advanced speech-processing strategies such as simultaneous analogue stimulation (SAS) and continuous interleaved samplers (CIS).[1,5] In this quest for improved function, Clarion® have developed a protective positioner that medializes the electrodes in an effort to improve electrical contact with the spiral ganglion cells within the modiolus.[6] It is hoped that this improved contact would concentrate the current produced, resulting in less current required to produce the same stimulus. Allied to this, less current dispersed through the cochlea would reduce potential side-effects such as facial nerve stimulation.[2]

TABLE IV

IMPEDANCE LEVELS MEASURED TWO MONTHS AFTER INSERTION OF ELECTRODE

	Channel 3		Channel 6	
Patient no.	Before	After	Before	After
1. JA	13	20	25	**24**
2. DM	22	22	19	24
3. DM	24	**14**	20	27
4. JB	14*	19	20	23
5. CW	22*	27	18*	23

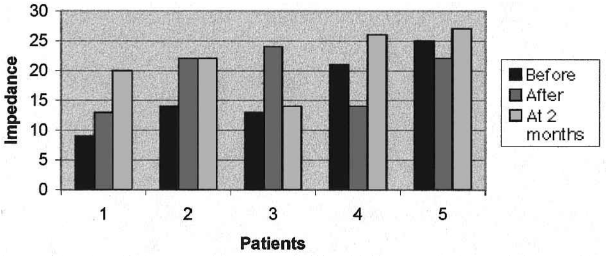

FIG. 3

Graphic representation of impedance levels measured at channel 3 before insertion, immediately afterwards and at two months.

This small group of five patients underwent the insertion of identical cochlear implants along with the electrode positioning system (Figure 5). Two parameters were measured, namely current units needed to reach the stapedial reflex threshold and the impedance measurements.

The stapedial reflexes were measured by positioning the microscope in order to have a clear view of the stapedius tendon. The cochlea was then stimulated with decreasing amounts of current, producing a stapedial reflex until the threshold was reached at channels 3 and 6.

It was expected that the current needed to reach the stapedial reflex threshold would decrease with medialization as there would be improved contact and therefore concentration of the current between the implant electrodes and spiral ganglion cells of the modiolus. This was shown to be the case in eight out of the 10 measurements taken but two electrodes showed an increase in current units needed. The measurement for JA in channel 6 was only marginally elevated and could be accounted for by human error but the increased threshold for patient DM in channel 3 was more than likely due to debris or air being trapped between the electrode and the modiolus.

Bone is known to have a higher impedance (or resistance) compared to the fluid of the scala tympani and thus the impedance recordings were expected to rise, as the medialization of the electrodes would result in greater contact with the bony modiolus. Three individual electrodes showed an initial drop in resistance at the time of insertion as shown in Table III, but they had risen when measured two months post-operatively. This could be explained by a degree of air-trapping between the electrode and the modiolus at the time of insertion. Gradual absorption of the air over a period of time would improve the readings. The drop of impedances in two electrodes at two months is a mystery as both electrodes showed an initial increase in their impedance value and both still appear to be working well at the present time.

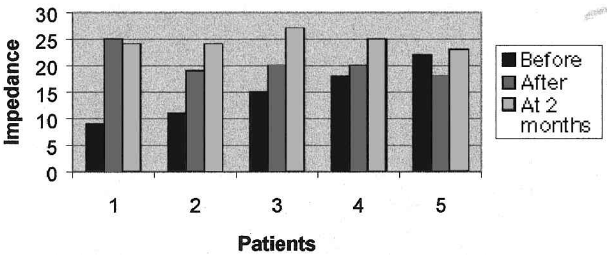

FIG. 4

Graphic representation of impedance levels measured at channel 6 before insertion, immediately afterwards and at two months.

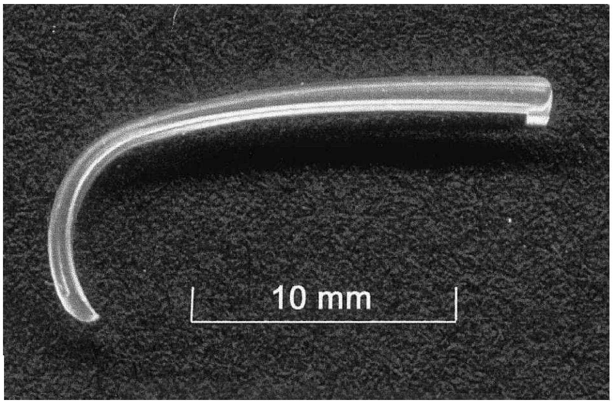

FIG. 5

Silastic positioner used to medialize electrode array of cochlear implant.

Many of the procedural steps for insertion of the Clarion® implant are shared by the implantation of other devices but there are some notable differences. In particular, a larger posterior tympanotomy and cochleostomy is needed to accommodate both the insertion tool and then the electrode positioning system.^{7} Insertion of the electrode-positioning device was also found to be taxing at times, particularly if space in the region of the posterior tympanotomy was limited.

Conclusion

The objective of this paper was to ascertain the effect of cochlear implant medialization with an 'electrode positioner' on the amount of current needed to stimulate the spiral ganglion cells and the impedance measurements between the electrodes and modiolus.

The small numbers in this study prevented statistically significant conclusions from being drawn. It does, however, appear that the electrode medialization produces a *trend* towards decreasing the current needed to reproduce a stapedial reflex threshold with correspondingly increased impedance values.

This study is presently ongoing and will form part of a bigger project once a larger group of patients with this particular cochlear implant plus electrode positioner have been included in the database.

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