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IS DEEP INSERTION OF THE COCHLEAR IMPLANT ELECTRODE ARR NECESSARY AND POSSIBLE?

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Hyaluronate (Healon TM) appears to be useful in achieving deeper electrode insertions than are generally achieved at present. However, biosafety studies are still being conducted. If found to be a safe technique, further work to explore different electrical stimulation strategies and speech processing schemes will also need to be undertaken. This work is ongoing.

Speech processing strategies for the multiple-channel cochlear implant utilise the tonotopic organisation of the basilar membrane (Tong and Clark 1985, McDermott 1991, Wilson et al 1991). This has proven effective. It has been shown that electrical stimulation of electrodes at different positions in the human scala tympani produces pitch sensations that generally become lower as the stimulating electrodes become more apical (Tong et al 1982, Tong and Clark 1985, Dorman et al 1990). However, with the insertion depths of the electrode array presently achieved, the lower range of pitch perception is limited to about 1000 Hz. As important speech information, particularly for vowels, is contained at frequencies lower than this level, it seems desirable to achieve deeper insertions of the electrode array.

In order to facilitate deeper insertions, hyaluronate (HealonTM) has been proposed as a lubricant when introducing the electrode array into the cochlea. Initial trials with implant patients suggest that hyaluronate may indeed aid deeper insertions (Lehnhardt 1993). Little research has been carried out in the use of hyaluronate in cochlear implant surgery. Therefore, before introducing this substance as part of the surgical protocol for our implant clinic, a number of important issues needed to be addressed. Firstly, can deeper insertions be achieved using hyaluronate? Secondly, will patients benefit from having electrodes inserted more deeply?

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Materials and Methods

In order to answer the first question, a human temporal bone study was carried out. Six fresh human temporal bones were harvested and implanted within 24 hours of death. The standard surgical approach described for cochlear implantation was used for all bones. A drop of hyaluronate was instilled into the cochleostomy and the electrode array coated with hyaluronate. The array was inserted until resistance was felt and then secured in place. After fixing with 10% neutral buffered formalin, the implanted bone was x-rayed to demonstrate the position of the electrode.

Four previously unused banded multiple-channel practice electrodes were used for insertion. These electrodes have identical dimensions and properties to the electrodes inserted in patients. Two of the electrodes were used for two implantations after carefully checking that the array was in no way damaged after the first insertion.

The x-rays were digitized using image analysis techniques, and the position of the electrodes carefully mapped in relation to the round window (RW) and superior semicircular canal (SSC). Using a technique described by Cohen et al (in press) the angular insertion depth of the electrode tip can be estimated. Controls used for this experiment were the post-operative x-rays of 22 patients who had been implanted without using hyaluronate as a lubricant. These x-rays were analyzed in a similar fashion to that described above and the insertion depths estimated.

In order to investigate the value of deep insertions, six patients in the Melbourne Cochlear Implant Clinic with the deepest insertions were assessed. In this group of patients, a particular attempt had been made to achieve deep insertions, and as such they are not representative of the experience of the clinic in general. All patients were using a bipolar plus one (BP+1) stimulation strategy. Pitch estimation studies were carried out in order to determine how pitch perception varied with the depth of the active electrode pair. Each patient was presented with a stimulus and instructed to assign a number to it in the range of 1-100 on the basis of their perception of the pitch. One indicated an extremely low pitch and 100 a very high pitch. The patients had performed similar tasks previously and were familiar with the scoring system.

Results

Insertion distances
A typical x-ray of the implanted bones is shown in Figure 1. The digitized image of the bands, SSC and RW superimposed upon the geometric spiral is shown in Figure 2.

For the six bones in the study, the depths of insertion ranged from 287-457 degrees. A student's t-test was used to compare the two groups and, as shown in Table 1, there was a statistically significant difference. Deeper insertions were seen in the group using Healon.

Pitch estimates
Insertion depths for the six patients ranged from 346-477 degrees. The pitch estimate produced by the active electrode pair was plotted against the angle of insertion of the electrodes (Figure 3). For S1, pitch perception reduced in a regular fashion as the active electrode pair became deeper indicating that the subject was getting useful pitch information from all the electrodes. However for S2, S4, S5 and S6 a sharp reduction in pitch perception occurred when the active electrode pair is at a depth of approximately 270 degrees. This was followed by a plateau of pitch estimates for deeper electrodes indicating that little useful pitch information was being provided to these subjects from the deeper electrodes. A similar situation was also seen for S3 with the drop in pitch estimates seen at 402 degrees.

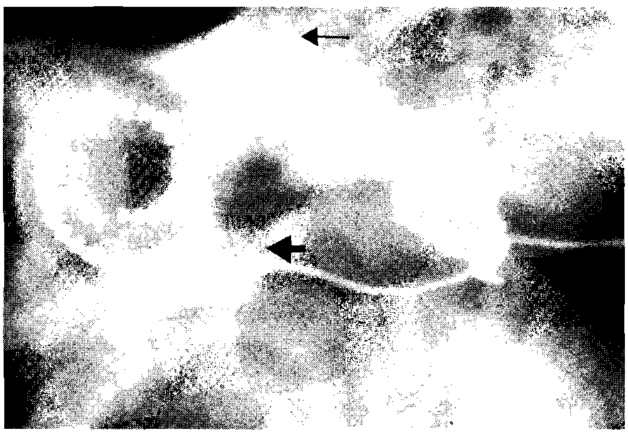

FIG. 1. X-ray of implanted temporal bone. Small arrow indicates marker in round window and large arrow indicates the superior semicircular canal.

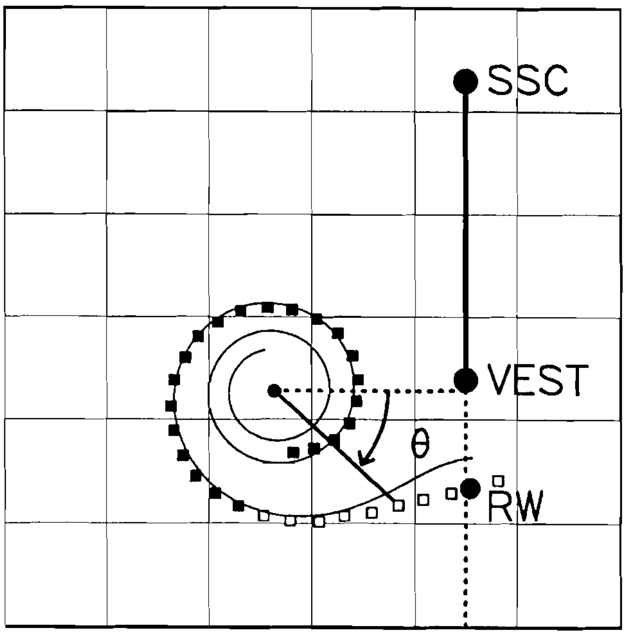

FIG. 2. The horizontal line intersecting the line joining the superior semicircular canal (SSC) and the centre point of the vestibule (VEST) represents the zero degree orientation.

Table 1

Mean angles of insertion at electrode 22 for temporal bones implanted with Healon and patients implanted without Healon.

	Temp Bones (n = 6)	Patients implanted without Healon (n = 22)	t-test
Mean deepest angle of insertion	411 S.D.=67	335 S.D.=74	p=0.034

Discussion

Insertion of the electrode array into the scala tympani of the human cochlea is associated with minimal damage if performed gently (Shepherd et al 1985). Injudicious use of force to push the electrode more deeply beyond the point of first resistance can result in significantly increased trauma (Kennedy 1989). A lubricant to reduce friction and facilitate deeper insertions of the electrode array is therefore a very attractive idea. Sodium hyaluronate, available as Healon (TM), has been used in ophthalmological surgery for a number of years. Its viscoelastic properties have been utilised to protect the epithelium of the anterior chamber of the eye during lens surgery, and to lubricate the intraocular lens (Miller and Stegmann 1983). An initial report using Healon as a lubricant indicated that deeper insertions were accomplished compared to insertions without Healon (Lehnhardt 1993). However, there is no quantitative assessment in the literature of the benefit of using Healon in order to aid deeper insertions of the cochlear implant electrode. This study has demonstrated that the use of Healon can indeed be useful in attaining deeper insertions in normally patent cochleas. Although we have therefore documented the usefulness of Healon, biosafety studies are being completed before it is used routinely in our clinic.

Having shown that it may be possible to insert the electrode more deeply on a regular basis, we must consider whether or not this is useful to implant patients. The unexpectedly low pitch estimates using BP+1 stimulation are certainly not ideal. There are a number of possible reasons for this. Producing deeper insertions may be associated with increased mechanical trauma which allows current to escape to the more apical regions rather than stimulating the specific target area. Alternatively, as the surviving dendrite population (with a lower threshold of stimulation than spiral ganglion cells) may be optimal in the apical regions (Clark et al 1988) current spread from active

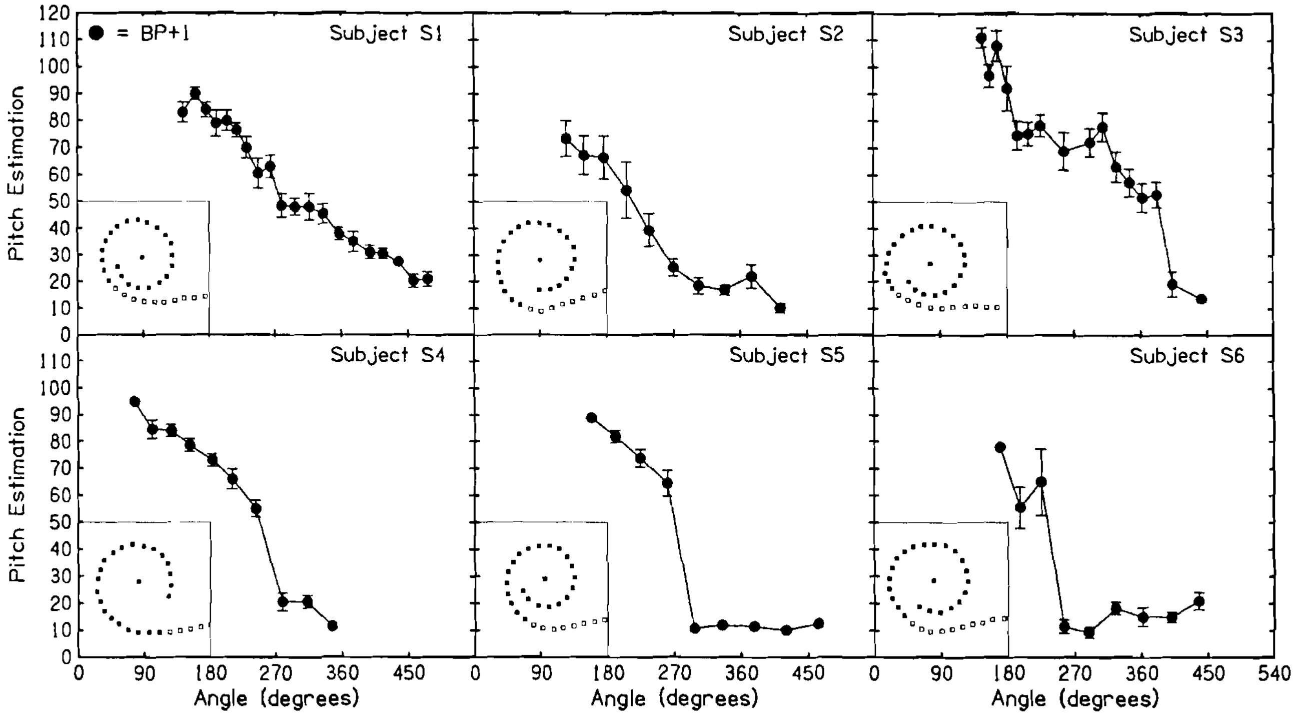

FIG. 3. The pitch estimates for the subjects with the deepest insertions plotted against insertion angle in degrees. The error bars indicate +/- 1 standard error around the mean. The inset in each graph is a representation of the depth of insertion for the subject.

electrodes beyond a certain depth of insertion may activate this region preferentially. The possibility of existing anatomical pathways within the cochlea to allow anomalous current distribution is the least likely explanation.

We have shown that Healon may be useful in achieving deeper insertions than are generally achieved at present. Deep insertions can provide some patients with useful pitch information, but the use of excessive force to achieve deep insertions must be cautioned against. Healon may reduce insertion trauma and the likelihood of current spread to non target regions of the cochlea. In order to extend the potential benefits of deep electrode insertion to more patients, work exploring different electrical stimulation strategies (eg monopolar) and modifying speech processing schemes is ongoing.

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