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Electrophysiological effects of slim straight intracochlear electrode position‡

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Abstract

Objective. The electrical current distribution of a cochlear implant electrode within the cochlea is essential for post-operative hearing performance. The slim straight electrode is designed to enable the placement of contacts in a lateral or medial direction to the modiolus. The electrophysiological effect of this different contact direction is so far unknown. The aim of this study was to determine the influence of intracochlear laterally or medially directed electrode contacts on electrophysiological behaviour.

Method. A slim straight electrode was inserted into the cochleae of five patients, and the neural response threshold was measured in a laterally and medially directed contact position. The cochleae in five temporal bone specimens were de-capped allowing an insertional observation of the contact position (lateral versus medial) of the electrode.

Results. There was no difference in neural response threshold between a lateral and a medial position of the contacts. Temporal bone study indicated no intracochlear torsion of the electrode.

Conclusion. Our study provides evidence that the intracochlear position of slim straight electrode contacts does not affect the neural response threshold.

Main Article

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Dr I Todt takes responsibility for the integrity of the content of the paper

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Introduction

Cochlear implantation is the treatment of choice for patients with profound-to-severe sensorineural hearing loss (SNHL) who retain residual hearing. The cochlear implant electrode is a central component of the implant–neuron interface, and its design plays an important role in preservation of residual hearing, intracochlear electrophysiological behaviour and speech comprehension.[1,2,3,4] Different electrode design, which focused on the different current distribution and hearing preservation, led to the development of three main types of electrodes: perimodiolar, midmodiolar and lateral wall electrodes. The design of perimodiolar and midmodiolar electrodes concentrated on the intracochlear current distribution, showing that a position close to the modiolus led to lower neural response thresholds, induced minor spread of electrical current and less interference between the channels.[5,6,7] In contrast, lateral wall electrodes were developed to preserve residual hearing. However, the disadvantages of using these electrodes are higher neural response threshold levels[6] and a higher risk of facial nerve stimulation.[8]

Lateral wall electrodes were designed with a contact to one side and a wing to the contralateral side to guide the contact to the side of the modiolus (slim straight lateral). It is assumed that this design led to a guided current spread in the direction of the modiolus with less electrode rigidity.

Since the wing at the electrode is on the contralateral side of the electrode contacts, a right-handed surgeon (as most surgeons are (75–95 per cent[9])) regularly inserts this kind of electrode in a right ear with the contacts in the direction of the modiolus. Using the wing to hold the electrode in a left ear with the right hand, the surgeon places the contacts away from the modiolus. These laterally positioned contacts might potentially lead to higher neural response thresholds with possible effects on stimulus levels, spread of excitation, canal interaction and power consumption (Figure 1).

The aim of the present study was to observe the intracochlear behaviour of electrodes in temporal bone in terms of a torsional position and to evaluate the different sided intracochlear contact placements and their neural response thresholds *in vivo*.

Materials and methods

A total of 5 patients were included in this prospective study (2 female, 2 male; mean age: 57.5 years; range: 31 to 84 years). The aetiology was sudden hearing loss in three cases, noise trauma in one case and was unknown in one case. The mean duration of hearing loss was 5.6 years (range: 1 to 20 years). The study inclusion criterion was implantation with the Nucleus® slim straight electrode (product 522). Exclusion criteria were patients with ossification, obliteration, neural deficiencies and residual hearing.

All included patients were implanted between 2017 and 2018 with a standard surgical procedure including a post-auricular transmastoid approach, a posterior tympanotomy

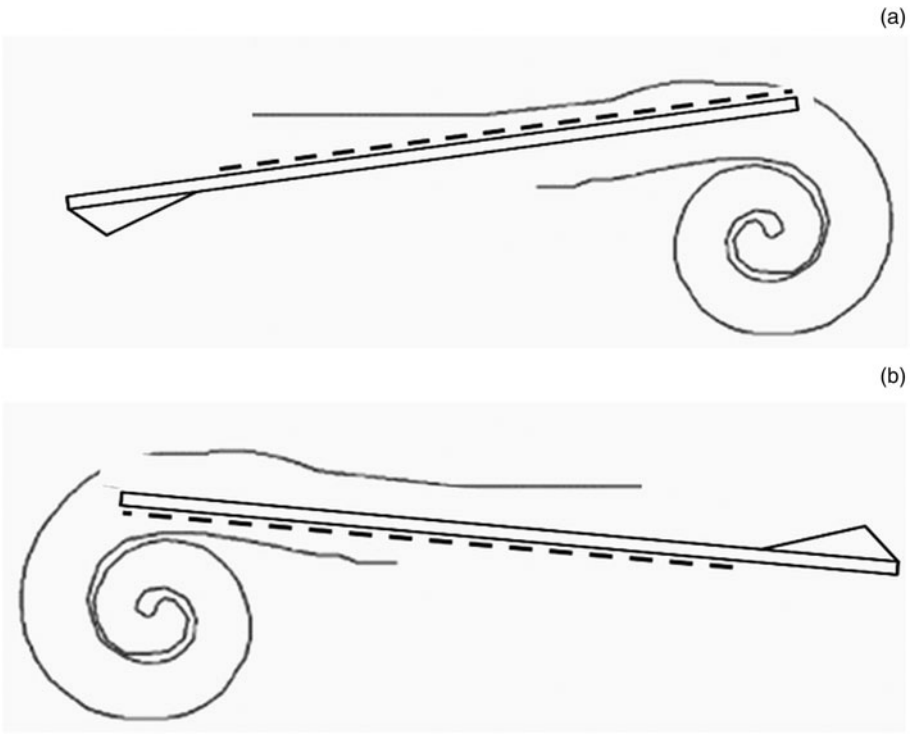

Fig. 1. Slim lateral electrode diagrams showing position of contacts and wing for (a) the right ear and (b) the left ear.

and a round window electrode insertion. Before initial insertion, the electrode was moisturised with triamcinolone. After the initial lateral contact positioning and electrophysiological measurement, the position was changed to a medial contact direction and measured again. Finally, the electrode and the round window were covered with fascia.

This study was reviewed and supported by the hospital review board of Klinikum Bielefeld (approval number: HNO-KLIBI-08-2017) and was conducted according to the principles expressed in the Declaration of Helsinki. The patients gave their written consent for participation in the study. The neural response threshold data and temporal bone observation data that were used to support the findings of this study are available from the corresponding author upon request.

Temporal bones

Five temporal bones were harvested, and the cochlea was drilled until a full visual assessment of the basilar membrane was possible. The basilar membrane was then removed to allow a visual observation of the electrode contact direction. Afterwards the slim straight electrodes were inserted two times up to 22 mm. Initially the insertion was with the contacts laterally directed, followed by the contacts being medially directed. The insertional procedure was microscopically evaluated, and photographs were taken.

Radiological evaluation

Determination of the electrode position was performed by cone beam computed tomography (CT) (NewTom VGI, Verona, Italy). The parameters were: field of view, 15 × 15 cm; 10.48 mAs; 20.52 mAs; 110 kV; 360°. The cone beam CT was followed by two-dimensional and three-dimensional reconstruction at an external workstation (NNT software, main station). One experienced surgeon and a neuroradiologist reviewed all radiological images post-operatively.

Data acquisition and neural response threshold evaluation

Neural response threshold data were obtained intra-operatively under sterile conditions in all included patients. Software-based neural response threshold recordings (Cochlear's Custom Sound® fitting software, version 4.4) were used (using auto-neural response threshold mode) to measure and evaluate the neural response thresholds. In each individual, all electrodes were measured and recorded.

All measurements were performed two times. The first condition was a laterally directed contact position, and the second condition was the medially directed contact position. Statistical evaluation was performed using SPSS® (version 24) statistical software.

Results

Temporal bone observations

We evaluated 5 temporal bones with a measured mean 'A' distance[10] (10.45 mm, SD, 0.18). The intracochlear behaviour of the electrode during the insertion showed no relevant torsion in terms of significant changes of contact direction independent of the size of the cochlea. In all cases, a wing directed contralateral direction of the contacts remained stable over the whole electrode length (Figure 2).

Neural response threshold measurements

In all cases, we measured the lateral and medial position of the contacts twice. There were no cases where the maximum current unit deviation of a single contact between the lateral and medial position of the contacts was larger than the maximum deviation between first and second neural response threshold measurement.

The mean neural response thresholds for lateral and medial position was 195.6 current units (lateral) versus 196.9 current units (medial). This difference was statistically not significant. Contact specific mean values are shown in Figure 3. The mean

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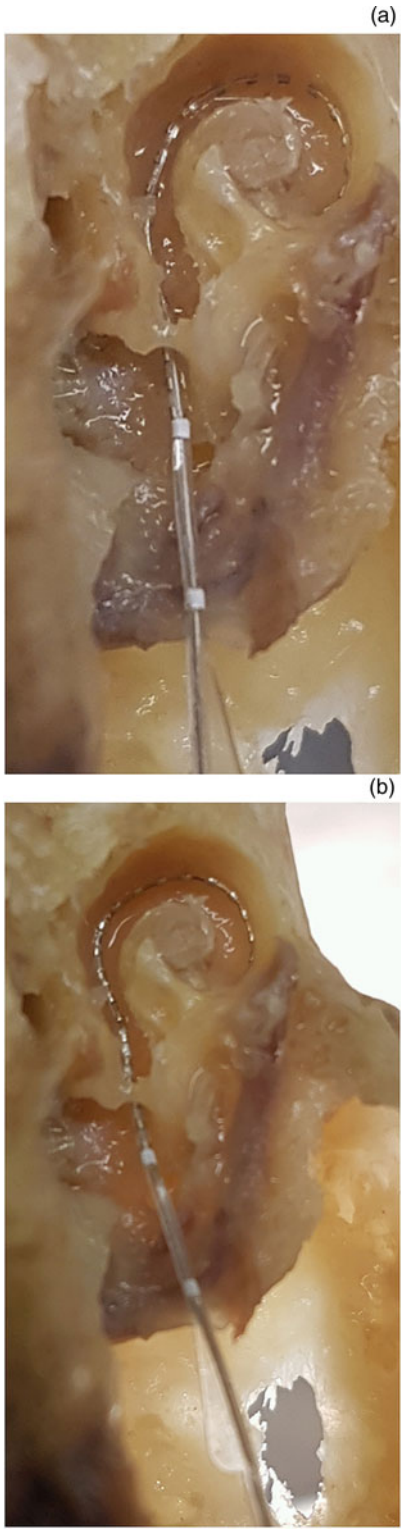

Fig. 2. Images showing temporal bone with an uncapped cochlea and electrode contact position. (a) Medial contact position and (b) lateral contact position.

current unit standard deviation between medial and lateral measurements was 10.5 current units (medial) versus 10.7 current units (lateral). The mean neural response thresholds for the first and second measurement were 196.2 current units and 196.4 current units, respectively. This difference was statistically not significant. The mean current unit standard deviation between the first and second measurements was 10.9 current units (first measurement) versus 10.5 current units (second measurement).

In all cases, a certain scala tympani position was visually verified by cone beam CT on the first post-operative day.

Discussion

Cochlear implantation is the safe and reliable procedure of choice for the treatment of profound-to-severe SNHL and patients with residual hearing. The position of the electrode array in the cochlea is fundamental for the interaction between the implant and the cochlear neuronal structures because it determines the localisation of current stimulation.

Other than local neural factors, the electrode position itself is of central importance for the threshold. In general, lateral wall electrodes are known to cause higher neural response thresholds.[6] Besides an effect on speech understanding, which is discussed, a higher frequency discrimination has been shown, which is assumed to be related to less channel interaction.[6,11] Several studies[3,4,12] showed that electrode position is a central factor affecting speech understanding. A scalar change and electrode tip folding has been shown to be detectable even by electrophysiological measurements.[13,14] The optional positive influence on the neural response threshold by a surgical modification has been evidenced by performing a so-called 'pull back' of a perimodiolar electrode.[15]

The manufacturer recommends insertion with the contacts in the direction of the modiolus. Since the electrode wing is contralateral to the contacts, the surgical procedure should be clear when using the wing for the insertion. This procedure and direction of contacts is clear for right ears when the right-handed surgeon holds the wing. Performing the same procedure in a left ear while holding the wing on the right side of the electrode as a right-handed surgeon led to an electrode contact direction away from the modiolus as shown in our experiments (Figures 1 and 2).

Our observations show that there is no effect of the contact position on neural response threshold in the slim straight electrode that was evaluated. This finding is in contrast to comparisons between lateral wall electrodes and perimodiolar electrodes and might be related to the relatively larger distance from the modiolus when comparing lateral wall electrodes with perimodiolar electrodes from the same producer.[6,16] Therefore, the relative distance difference between lateral wall electrode contacts at different directions is smaller than for perimodiolar electrodes in cases of scalar translocation[14] or with or without a stylet.[16]

- With slim straight electrodes, the direction of electrode contacts during cochlear implant electrode insertion in relation to the modiolus is assumed to be important for surgical handling and electrophysiological threshold
- Based on temporal bone observations, electrode torsion does not occur during insertions with modiolus distant electrode contact direction
- Intra-operative electrophysiological measurements evidence that contact direction has no impact on neural response threshold in slim straight electrodes

From this finding we can assume two things. (1) We can assume that there is a ball-like current spread around each contact and not a cone-like current spread on the side of the electrode contacts. A cone-like current spread should have shown a higher neural response threshold for the lateral position. This is not the case. (2) Out of the missing neural response threshold difference of the different contact positions, we can assume that a bilateral contact placement has no advantage

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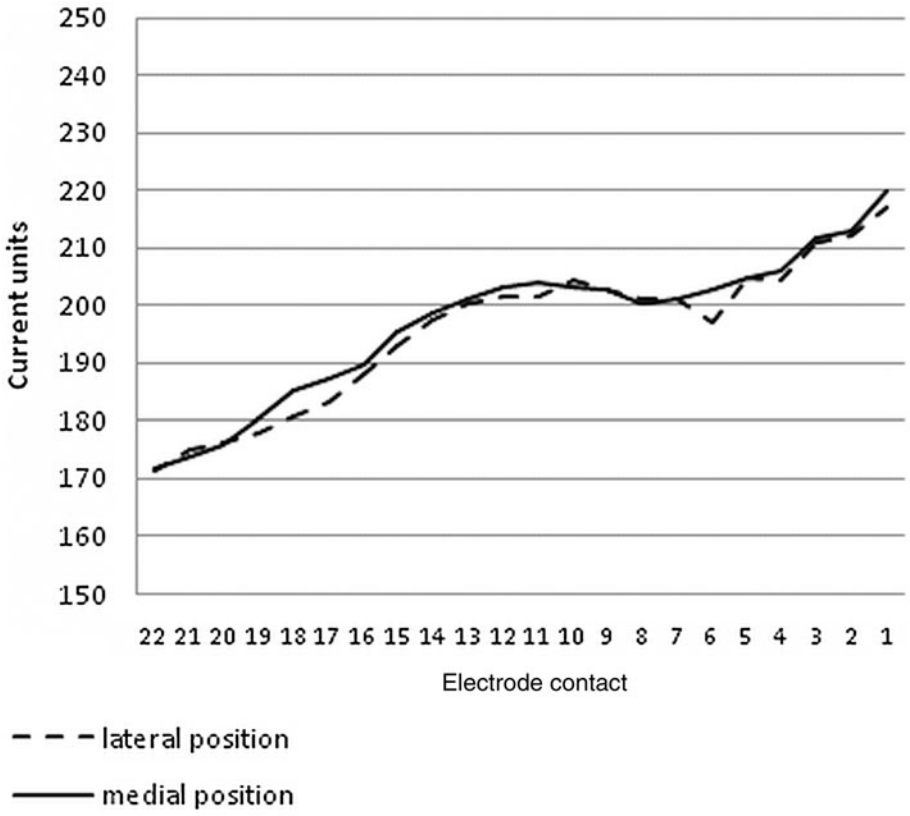

Fig. 3. Graph showing mean neural response threshold of medial and lateral contact positions.

(EVO® electrode, Med-El electrodes) in comparison to a unilateral placement in terms of neural response threshold.

Conclusion

The contact direction of slim straight cochlear implant electrodes has no impact on the intra-operative neural response threshold.

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Competing interests. None declared

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