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Comparison of electrically evoked stapedial reflexes in patients with cochlear implants surgically implanted using Veria and posterior tympanotomy approaches

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Main Article

P Jawahar Antony takes responsibility for the integrity of the content of the paper

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Abstract

Objective. The study aimed to compare ipsilateral and contralateral electrically evoked stapedial reflex thresholds in children with a unilateral cochlear implant surgically implanted either through Veria or posterior tympanotomy approaches.

Methods. Forty-nine children using cochlear implants were studied, of whom 27 underwent the Veria approach and 22 underwent the posterior tympanotomy approach. The electrically evoked stapedius reflex thresholds were measured ipsilaterally and contralaterally by stimulating four equally spaced electrodes.

Results. The ipsilateral electrically evoked stapedius reflex threshold was absent in all four electrodes in the children implanted using the Veria approach. However, the ipsilateral electrically evoked stapedius reflex threshold was present in 70 per cent of the children implanted using the posterior tympanotomy approach. The contralateral electrically evoked stapedius reflex threshold was present in most of the children for both surgical approaches.

Conclusion. The presence of the ipsilateral electrically evoked stapedius reflex threshold varies depending on the surgical technique used for cochlear implantation. However, contralateral reflexes are present in the majority of children using cochlear implants, irrespective of the surgical approach.

Introduction

Mapping cochlear implants in the paediatric population is a challenge, especially while setting the comfort or the most comfortable level. Accurate setting of the comfort or the most comfortable level has been noted to have a greater impact on speech perception compared to threshold measurements.[1,2] It has been shown that reducing the threshold levels by 25–30 current units does not affect speech perception.[2] Conversely, it has been noted that a reduction in the actual comfort levels can negatively impact speech perception.[1,2] Dawson *et al.*[1] found that inadequate or unbalanced comfort levels adversely affect the amplitude cues and spectral information important for phoneme perception. In addition, the importance of setting comfort levels during mapping has been highlighted by others.[3–5]

Both behavioural and objective measures have been used to set comfort or most comfortable levels during cochlear implant mapping. For adults and older children, behavioural comfort or most comfortable levels are usually set using loudness scaling techniques.[3,5] However, in young children who are unable to give consistent responses regarding loudness growth, such behavioural responses are not used. It is recommended that comfort levels be set using a behavioural observation technique with the device switched on.[5] Such a subjective technique may be inadequate when children do not demonstrate appropriate behavioural responses.

In the absence of valid ways to set comfort levels behaviourally in young children, the use of objective techniques is recommended, to cross-verify the behavioural responses.[4,6] These objective tools include electrically evoked compound action potentials and electrically evoked stapedius reflex threshold measurements. The utility of the electrically evoked stapedius reflex threshold to set the comfort levels while mapping cochlear implants has been well established.[7–13] The electrically evoked stapedius reflex threshold is reported to be the minimal amount of electrical stimulation that elicits a measurable contraction of the stapedius muscle in the middle ear. It is considered to support faster and safer programming of the cochlear implant, especially in patients who give inconsistent responses and/or have multiple problems.[14,15] Moderate to strong correlations have been observed to exist between behavioural comfort levels and comfort levels measured through the electrically evoked stapedius reflex threshold.[10,12,16–18] In addition, Wolfe and Kasulis[19] showed that maps with comfort levels set using the electrically evoked stapedius reflex threshold yielded better speech recognition scores than programmes with comfort levels set using conventional behavioural measures. Bresnihan and colleagues[20] reported that electrically evoked stapedius reflex threshold based maps provide improved comfort for

speech and environmental sounds in children using cochlear implants, resulting in them using their device for longer durations. Thus, the reviewed literature indicates that the electrically evoked stapedius reflex threshold is a reliable and consistent tool to set comfort levels.

In order to measure the electrically evoked stapedius reflex threshold, the middle-ear structures are required to be intact, according to Wolfe and colleagues.[21] They noted that any condition which changes the mechano-acoustical properties at the tympanic membrane could have a disproportionate effect on acoustic admittance measures. It was also observed that earlier middle-ear pathologies could disrupt the normal functioning of the middle ear. Clinically insignificant middle-ear changes were found to drastically affect measurement of the stapedial reflex.

The two widely used cochlear implant surgical approaches are the mastoidectomy with facial recess approach, also known as the posterior tympanotomy approach,[22] and the suprameatal approach, also known as the Veria technique.[23,24] Posterior tympanotomy, which requires a mastoidectomy, uses the facial recess to insert the cochlear implant electrodes from the mastoidectomy to the middle ear.[25,26] In contrast, the Veria technique involves drilling a suprameatal tunnel, and the electrodes are introduced into the middle ear.[27,28] It has been reported that elevation of the tympanomeatal flap of the eardrum, as well as drilling near the incus, may cause conductive hearing loss in the implanted ear.[28]

To set the comfortable levels during mapping of cochlear implants in children, audiologists frequently use the electrically evoked stapedius reflex threshold, as recommended by several researchers in the literature. However, there is a possibility that the surgical technique used during cochlear implant surgery may affect the electrically evoked stapedius reflex threshold measurements carried out during mapping. Hence, the present study aimed to compare the ipsilateral and contralateral electrically evoked stapedius reflex thresholds in children unilaterally implanted using Veria or posterior tympanotomy surgical approaches.

Materials and methods

Participants

A total of 49 children who had undergone unilateral cochlear implant surgery were studied. Among them, 27 children (mean age of nine years) were implanted using a posterior tympanotomy approach, and the remaining 22 children (mean age of six years) were implanted using the Veria technique. Children were only included in the study if the computed tomography and magnetic resonance imaging reports indicated no cochlear or cochlear nerve anomalies.

The children used cochlear implants manufactured by Advanced Bionics ($n = 3$), Cochlear Nucleus ($n = 31$), Oticon/Neurelec Digisonic® ($n = 12$) and Med-El ($n = 3$). Table 1 details the numbers of children using devices of each manufacturer who underwent the Veria and posterior tympanotomy approaches.

It was ensured that the children had no middle-ear problems or illness at the time of evaluation. The absence of a middle-ear problem was confirmed by an ENT surgeon, as well as by the presence of type 'A' or 'As' tympanograms[29] in both ears, ipsilateral and contralateral to the cochlear implant.

The implant age of these children ranged from one to four years. In addition, the children were included only if they could co-operate and sit still for the duration of the test, without the need for sedation. Prior to the evaluation, informed consent was taken from the patients' caregivers, following the ethical guidelines of the institute.[30]

Table 1. Numbers of children using different cochlear implants who underwent Veria or posterior tympanotomy surgery

Cochlear implant manufacturer	Veria approach	Posterior tympanotomy approach
Advanced Bionics	0	3
Cochlear	12	19
Med-El	2	1
Oticon Medical (formerly Neurelec)	8	4

Data represent numbers of children implanted

Procedure

Otoscopic examination of both ears was conducted for each child prior to the recording of stapedial reflexes, to rule out the presence of impacted wax or any obstruction in the ear canal. To measure stapedial reflexes, a calibrated immittance meter (GSI Tympstar; Grason-Stadler, Eden Prairie, Minnesota, USA) was set to the contralateral reflex decay mode, with a time base of 60 seconds to view the reflexes. Contralateral reflexes were recorded by inserting the immittance probe to the ear contralateral to the cochlear implant, and ipsilateral reflexes were measured from the ear with the cochlear implant. The measurements were conducted with the cochlear implant speech processor connected to the company-specific programming software through the required interface. The electrically evoked stapedius reflex threshold was measured on four equally spaced electrodes that represented low, low-mid, mid-high and high frequencies.

The programming software packages of the different companies were used to present the electrical stimuli, and the presences of reflexes were observed on the screen of the immittance meter. The stimuli were initially presented five steps below the earlier set comfort levels. The current level or the pulse width was increased by one step until the electrically evoked stapedius reflex threshold was observed, and was decreased by one step until the electrically evoked stapedius reflex threshold disappeared. In order to confirm the presence of the electrically evoked stapedius reflex threshold, the levels were increased again in one step until an electrically evoked stapedius reflex threshold was observed. A deflection in the admittance value either in the positive or negative direction, time-locked to the electrical stimulation, was considered as the presence of a stapedial reflex. The minimum current or pulse width that brought about a consistent deflection in the stapedial reflex was noted as the stapedial reflex threshold. The presence of a reflex was confirmed if an increase in the current or pulse width resulted in a corresponding increase in its amplitude. The presence of reflexes was independently confirmed by two experienced audiologists.

Test–retest reliability of the measurements was carried out on four children who that undergone posterior tympanotomy and four children who had undergone a Veria surgical procedure. All children were measured within two months of initial electrically evoked stapedius reflex threshold recording, ensuring that they had no middle-ear problem during the intervening period.

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Analyses

The data obtained were tabulated and subjected to statistical analyses using SPSS® software (version 20). As the data were in a nominal scale, non-parametric statistics were used. Both descriptive and inferential statistics were carried out.

Results

We compared both the ipsilateral and the contralateral electrically evoked stapedius reflex thresholds of patients who had undergone the Veria technique with those who underwent the posterior tympanotomy surgical approach.

Comparison of electrically evoked stapedius reflex thresholds

The percentages of ears where the stapedius reflex threshold could be measured for each of the surgical approaches (Veria and posterior tympanotomy technique) are provided in Figure 1. These values are given separately for the ipsilateral and contralateral electrically evoked stapedius reflex thresholds. The data had to be converted to percentages as the numbers of individuals who had undergone each of the surgical techniques differed.

The ipsilateral electrically evoked stapedius reflex threshold was absent in all the participants who underwent the Veria technique (Figure 1). This absence was irrespective of the electrodes tested (Figure 2). However, the ipsilateral electrically evoked stapedius reflex threshold was present in 70.3 per cent of the patients who had undergone the posterior tympanotomy approach, in at least one of the electrodes tested (Figure 1). Additionally, in those who had undergone the posterior tympanotomy approach, the percentage of children with the ipsilateral electrically evoked stapedius reflex threshold present was higher for the electrodes representing the lower frequencies and decreased steadily in the electrodes representing the higher frequencies (Figure 2).

The contralateral electrically evoked stapedius reflex threshold was present in 86.3 per cent of those who underwent the Veria technique and in 92.5 per cent of those who underwent the posterior tympanotomy approach, in at least one of the electrodes tested (Figure 1). As was seen with the ipsilateral electrically evoked stapedius reflex threshold, the percentage

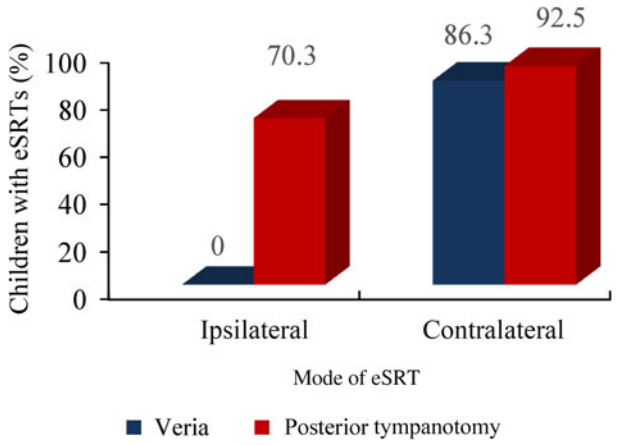

Figure 1. Percentages of children with ipsilateral and contralateral electrically evoked stapedius reflex thresholds (eSRTs) who underwent the Veria or posterior tympanotomy surgical approaches (includes children who had electrically evoked stapedius reflex thresholds present in any one of the electrodes tested).

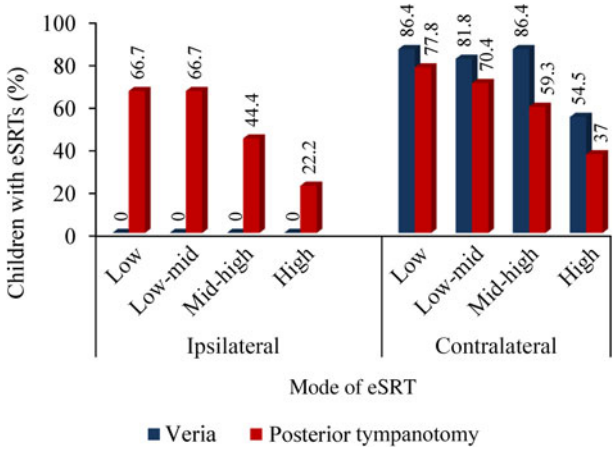

Figure 2. Percentages of electrically evoked stapedius reflex thresholds (eSRTs) in the ears ipsilateral and contralateral to the cochlear implant, in children who underwent Veria or posterior tympanotomy surgical approaches, for each of the four different electrodes (representing low, low-mid, mid-high and high frequencies).

of contralateral electrically evoked stapedius reflex thresholds decreased from low to high frequency electrodes, in both of the surgical approaches (Figure 2).

A Mann–Whitney U test was performed to compare the electrically evoked stapedius reflex thresholds between the two surgical procedures. The results indicated significant differences in the ipsilateral electrically evoked stapedius reflex thresholds between the two surgical approaches for the electrodes representing the low frequencies ($U = 99$, $p < 0.001$, $r = -0.68$), low-mid frequencies ($U = 99$, $p < 0.001$, $r = -0.68$), mid-high frequencies ($U = 165$, $p < 0.001$, $r = -0.50$) and high frequencies ($U = 231$, $p = 0.001$, $r = -0.33$). However, there was no significant difference in the contralateral electrically evoked stapedius reflex thresholds between the two surgical approaches for the low frequency electrodes ($U = 271$, $p = 0.44$), low-mid frequency electrodes ($U = 263$, $p = 0.35$) or high frequency electrodes ($U = 245$, $p = 0.22$); a significant difference was observed for the mid-high frequency electrodes ($U = 216$, $p = 0.03$, $r = -0.29$).

Comparison of threshold presence across electrodes

The numbers of times the electrically evoked stapedius reflex threshold occurred across the electrodes (representing low, low-mid, mid-high and high frequencies) were compared using a McNemar test for correlated proportions. For those patients who underwent the posterior tympanotomy approach, this was carried out both for the ipsilateral and contralateral electrically evoked stapedius reflex thresholds. However, for those who underwent the Veria technique, only the occurrences of the contralateral electrically evoked stapedius reflex threshold between the four electrodes were compared, as there was no ipsilateral electrically evoked stapedius reflex threshold for any of the electrodes in these patients.

In those who underwent the posterior tympanotomy approach, the ipsilateral electrically evoked stapedius reflex threshold was significantly different between: low and high frequency electrodes ($\chi^2(1, 26)$, $p = 0.007$), low-mid and high electrodes ($\chi^2(1, 26)$, $p = 0.003$), and mid-high and high electrodes ($\chi^2(1, 26)$, $p = 0.031$). For the contralateral electrically evoked stapedius reflex threshold, there was a significant difference between low and high frequency electrodes ($\chi^2(1, 26)$, $p = 0.006$), and between low-mid and high frequency electrodes ($\chi^2(1, 26)$, $p = 0.008$). In contrast, among those who

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underwent the Veria approach, for the contralateral electrically evoked stapedius reflex threshold there were no significant differences between: low and mid-low frequency electrodes ($\chi^2(1, 19)$, $p = 1.0$), low and mid-high frequency electrodes ($\chi^2(1, 19)$, $p = 1.0$), low and high frequency electrodes ($\chi^2(1, 19)$, $p = 0.63$), low-mid and mid-high electrodes ($\chi^2(1, 19)$, $p = 1.0$), low-mid and high frequency electrodes ($\chi^2(1, 19)$, $p = 0.21$), and high-mid and high frequency electrodes ($\chi^2(1, 19)$, $p = 0.063$). The information regarding the significant differences is shown in Figure 3.

The occurrences of electrically evoked stapedius reflex thresholds across the two surgical techniques for the ipsilateral and contralateral responses were also compared, using the McNemar test for correlated proportions. There was a significant difference between the ipsilateral and contralateral electrically evoked stapedius reflex thresholds in patients who underwent the Veria approach for: low frequency electrodes ($\chi^2(1, 19)$, $p < 0.001$), mid-low frequency electrodes ($\chi^2(1, 19)$, $p < 0.001$), mid-high frequency electrodes ($\chi^2(1, 19)$, $p < 0.001$) and high frequency electrodes ($\chi^2(1, 19)$, $p = 0.001$). There were no such significant differences between the ipsilateral and contralateral electrically evoked stapedius reflex thresholds in the posterior tympanotomy approach patients for: low frequency electrodes ($\chi^2(1, 26)$, $p = 0.45$), mid-low frequency electrodes ($\chi^2(1, 26)$, $p = 1.0$), mid-high frequency electrodes ($\chi^2(1, 26)$, $p = 0.45$) and high frequency electrodes ($\chi^2(1, 26)$, $p = 0.21$).

In order to check the test–retest reliability of the electrically evoked stapedius reflex thresholds, seven children (three Veria and four posterior tympanotomy approach patients) were re-evaluated within a one-month period. The kappa co-efficient test of reliability was manually calculated.[31] The kappa co-efficient was 1 (perfect agreement) for all the electrodes in both the Veria and posterior tympanotomy approach groups, except for the mid-high electrode for the posterior tympanotomy approach where the kappa co-efficient was 0.75 (indicating substantial agreement). From the kappa results, it is evident that there is high test–retest reliability of the electrically evoked stapedius reflex threshold when measured at two different times.

Discussion

The results of this study, which compared the electrically evoked stapedius reflex threshold in children implanted using one of two different surgical techniques (Veria or posterior tympanotomy approaches), are discussed, comparing both the ipsilateral and contralateral reflexes, as well as between the electrodes.

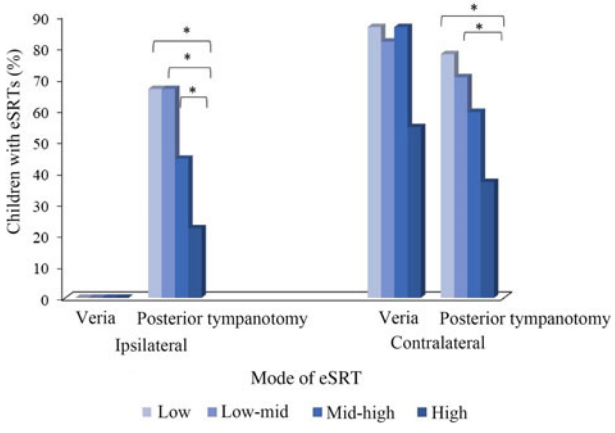

Figure 3. Significant differences (indicated by asterisks) of ipsilateral and contralateral electrically evoked stapedius reflex thresholds (eSRTs) on four different electrodes in children who underwent Veria or posterior tympanotomy surgical approaches.

The results indicated that the ipsilateral electrically evoked stapedius reflex threshold was absent in patients who underwent the Veria approach. This could be because of the technique's procedure, which involves elevation of the tympanomeatal flap and drilling near the incus.[28] Elevation of the posterior tympanomeatal flap, which is delicate, has been noted to lead to tympanic membrane perforations during the Veria surgery.[32] Further, Guevara and colleagues[33] reported that the incus may be removed in some patients who undergo the Veria approach. In the present study, none of the children had perforations, as was evident from the tympanograms, nor did they have their incus removed or electrode carrier tucked around the incus, which could have limited the mobility of the ossicular chain. However, there must have been some changes in the mechano-acoustical properties of the middle ear, resulting in an absence of the ipsilateral electrically evoked stapedius reflex threshold. It has been noted in the literature that any condition which changes the mechano-acoustical properties of the tympanic membrane may have a disproportionate effect on acoustic admittance measures.[21] All or any of these factors may have played a role in altering the middle-ear structures responsible for reverse transduction of the stapedial reflex, leading to the ipsilateral reflexes being absent in the children who underwent the Veria approach. This is true for the ipsilateral electrically evoked stapedius reflex threshold measured on all four electrodes representing the low, mid-low, mid-high and high frequencies.

In contrast with the Veria technique patients, both ipsilateral and contralateral reflexes were present in patients who underwent posterior tympanotomy. As the posterior tympanotomy approach does not involve manipulations of the tympanic membrane and other middle-ear structures, the reverse transduction required for eliciting the acoustic reflex would not have been hampered in these children. However, only 70 per cent of patients had the ipsilateral electrically evoked stapedius reflex threshold present with the posterior tympanotomy approach. The literature similarly reveals that the electrically evoked stapedius reflex threshold can be measured successfully only in about 63–84 per cent of the participants.[4,34–37] While no reason was given for the absence of reflexes by Caner *et al.*,[34] Gordon and colleagues[4] ascribed the absence of the electrically evoked stapedius reflex threshold to the lack of co-operation of the children, linked to loud stimuli. In the present study, all the children were co-operative. Hence, other reasons such as subtle defects in the middle-ear structures prior to the surgery could have resulted in the reflexes being absent in those who had undergone posterior tympanotomy.

Across the frequencies, the percentage of children with the contralateral electrically evoked stapedius reflex threshold decreased from the low to high frequency electrodes, in both approaches. This absence or instability of stapedial reflexes has been observed for high frequency acoustical stimuli in individuals with normal hearing. Sagalovich and colleagues[38] noted that when the frequency of the stimulus used to elicit stapedial reflex is increased, there is a reduction in amplitude and increased instability of the reflex. A high frequency activator such as a 4 kHz tone is not regularly used while evaluating acoustical reflexes, because of the elevation or absence of stapedial reflexes in normal hearing individuals. This has been ascribed to the adaptation seen on the presentation of the stimuli.[39,40] Hence, the absence of the electrically evoked

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stapedius reflex threshold seen in the higher frequencies in this study's patients could be for reasons similar to those in acoustic reflexes. Between the two surgical techniques, there was a significant difference in the electrically evoked stapedius reflex threshold obtained in the contralateral ear at the mid-high electrode. However, the effect size was found to be small, indicating that other co-variables could have influenced the results. It is hence recommended that the findings be further explored within a larger study sample.

The test–retest reliability was very high, irrespective of the surgical technique used (Veria or posterior tympanotomy approach). This indicates that the electrically evoked stapedius reflex threshold is a reliable and stable tool. This reliability in the electrically evoked stapedius reflex threshold is seen across all the electrodes that were evaluated. Literature also reveals a high test–retest reliability of 0.88 for the electrically evoked stapedius reflex threshold measured in children using cochlear implants.[41]

- The electrically evoked stapedius reflex threshold is a reliable objective measure used for mapping cochlear implants
- This threshold is effective for cochlear implant mapping in children not co-operative with behavioural measures
- Comparison of electrically evoked stapedius reflex thresholds between different surgical approaches in the ipsilateral ear has not been reported previously
- This study revealed a difference in the presence of the electrically evoked stapedius reflex threshold with different surgical approaches used for cochlear implantation
- The surgical approach has implications when measuring the electrically evoked stapedius reflex threshold and when mapping paediatric cases using this objective measure

In general, it was observed that the ipsilateral electrically evoked stapedius reflex threshold had lower amplitude growth with increased current levels than the contralateral electrically evoked stapedius reflex threshold. In addition, the ipsilateral electrically evoked stapedius reflex threshold required more current levels to obtain observable reflexes. Further, unlike the typical downward shift in reflexes, the ipsilateral electrically evoked stapedius reflex threshold showed an upward shift (increase in admittance) in five of the children who had undergone the posterior tympanotomy approach. This upward shift in reflex has been reported earlier with acoustical stimulation when obtaining the ipsilateral stapedial reflex.[42] However, the upward shift of the stapedial reflex with electrical stimulation is not reported in the literature. The reasons for this upward shift require further probing.

The findings of the present study suggest that use of the electrically evoked stapedius reflex threshold may not be possible while mapping patients who undergo bilateral cochlear implantation using the Veria technique. However, it also may not be measurable in approximately 30 per cent of bilateral cochlear implant users who undergo the posterior tympanotomy approach. Clinicians will have to rely on other methods to estimate the comfort levels in these individuals. In those with unilateral cochlear implants, the contralateral electrically evoked stapedius reflex threshold can be measured to estimate the comfort levels, irrespective of whether Veria or posterior tympanotomy approaches are used.

Conclusion

This study indicated that ipsilateral and contralateral electrically evoked stapedius reflex thresholds in children vary depending on whether they underwent cochlear implant surgery using a Veria or posterior tympanotomy approach. The ipsilateral electrically evoked stapedius reflex threshold was absent in all four electrodes measured in all children who underwent the Veria approach. However, the ipsilateral electrically evoked stapedius reflex threshold was present in approximately 70 per cent of those children who were implanted using the posterior tympanotomy approach. In the ear contralateral to the cochlear implant, the electrically evoked stapedius reflex threshold was present in patients who underwent either surgical approach. The study findings have implications for setting comfort levels during mapping in individuals who are unable to give reliable behavioural responses for the same.

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Competing interests. None declared

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