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Electrode contact estimation based on preoperative versus postoperative imaging as a basis for anatomy-based fitting

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Abstract: Anatomy-based fitting (ABF) has the potential to lead to better outcomes than conventional clinically-based fitting (CBF). It has already been shown that anatomy-based fitting based on postoperative imaging (postopABF) can improve speech understanding. Moreover, it was demonstrated that patients preferred anatomy-based fitting maps based on preoperative imaging (preop ABF) over CBF. The goal of this study was to examine if a difference between preopABF and postopABF could be observed. Via the software OTOPLAN4 (CAScination, MED-EL) the electrode position was calculated based on preoperatively, as part of the clinical routine, obtained imaging (CT or MRI). If necessary, after the cochlear implantation surgery the selected electrode array was adapted if a different array was chosen intraoperatively. This data was exported into the fitting software MAESTRO to enable a preopABF. The same process was done based on postoperative imaging (CT) so that 1) the frequency bands were compared between preopABF and postopABF data and 2) the difference was displayed in semitones. 27 Patients could be included who got a postoperative CT scan. In addition, subjective tinnitus and dizziness or imbalance issues did not significantly change from the pre-operative appointment over the first fitting to the control fitting one month later. In this study, we could show that there is no significant difference between apical to medial and a significant difference for medial to basal electrode contacts between the preopABF and postopABF regarding the frequency bands. Thus, preopABF is an easy, clinically practicable way to implement ABF, which is promising to lead to better outcomes without extra costs and the radiation burden that comes with postopABF. If patients subjectively prefer either preopABF or postopABF is still to be examined.

Keywords: anatomy-based fitting, tonotopic mismatch, robotic surgery, cochlear implantation

1 Introduction

Meanwhile, cochlear implantation is a standard treatment option for people with severe sensorineural hearing loss [1]. Still, speech understanding after implantation remains highly variable. Different contributors to speech understanding have already been discovered, one of them being the tonotopic mismatch, meaning a different stimulation location in the cochlea that the cochlear implant activates than the natural sound would. Different influencing factors have been analyzed to reduce the tonotopic mismatch (electrode array, electrode array insertion depth, electrode array position, surgical approaches (round window versus cochleostomy), et cetera) [2, 3]. The electrode array position is a main factor that creates significant place-pitch dissonance if not considered. Anatomy-based fitting (ABF) takes this into account: After obtaining a CT or MRI scan, a new surgical planning software, OTOPLAN (CAScination, MED-EL) can demonstrate the exact electrode array position in that scan, which enables an individual fitting for every patient based on his anatomy. It could be shown that using ABF based on postoperative CT scans (postopABF) can lead to a better speech understanding as it reduces the place-pitch mismatch [4]. However, postoperative CT scans are not common clinical practice, costly, and represent a considerable radiation burden.

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However, the preoperatively regularly performed imaging can also be used to calculate the expected electrode position for the different electrode arrays (and can even be changed postoperatively if a different electrode array was chosen intraoperatively) and represent the basis for ABF (preopABF). It was demonstrated that patients preferred anatomy-based fitting maps based on preoperative imaging (preopABF) over clinically based fitting (CBF) [4]. The goal of this study was to examine if a difference between preopABF and postopABF could be observed. In addition, we analyzed the change in tinnitus level and dizziness or imbalance issues over time in our study group where we used a slow and steady inserting robot for intra-cochlear placement of the cochlear implant electrode array [5].

2 Methods

Via the software OTOPLAN4 (CAScination, MED-EL) the electrode position was calculated based on preoperatively, as part of the clinical routine, obtained imaging (CT or MRI). During the CI surgery, RobOtol cochlear electrode array insertion by Collin SAS was used. RobOtol enables a slow (down to 0.1mm/s) and steady insertion of the electrode array into the patients' cochleae using its cochlear implant electrode holder [5].
If necessary, after the cochlear implantation surgery the selected electrode array was adapted if a different array was chosen intraoperatively. This data was exported into the fitting software MAESTRO to enable a preopABF. The same process was done based on postoperative imaging (CT) and the frequency bands were compared between preopABF and postopABF data. In addition, the difference between pre- and postoperative data was evaluated in semitones to represent the subjective tone perception and respect the logarithmic scaling on the human cochlear distribution [6].
27 patients could be included in this project's preliminary data analysis fulfilling all requested data characteristics. Of these, twelve patients were men and fifteen women. The mean age at cochlear implantation was 60.15+-15.00 years. Thirteen right ears and fourteen right ears were implanted.
Preoperatively, patients' tinnitus and dizziness or imbalance issues were recorded anamnestically. Seven patients reported no tinnitus, five reported tinnitus level I, eight reported tinnitus level II, seven reported tinnitus level III and no patient reported tinnitus level IV before CI surgery [7]. Twelve patients reported no dizziness/ imbalance, seven reported a mild disorder, seven reported moderate disorder, and one patient had a severe disorder.

3 Results

All study patients analyzed in this work received a cochlear implant type "MED-EL SYNCHRONY2 S-VECTOR". In four of them, the cochlear implant had the 34mm-long FLEX34 electrode array [8, 9]. For eleven patients, the thin 31.5mm-long FLEXSOFT electrode array was selected. In two patients, the thin 28mm-long FLEX28 electrode array was selected. Ten patients received the 31.5mm-long STANDARD electrode array.
For all study patients, we compared the electrode contact positions of preoperative estimation by OTOPLAN4 in comparison to the postoperative electrode positions using CT imaging (see **Figure 1** and **Figure 2**).

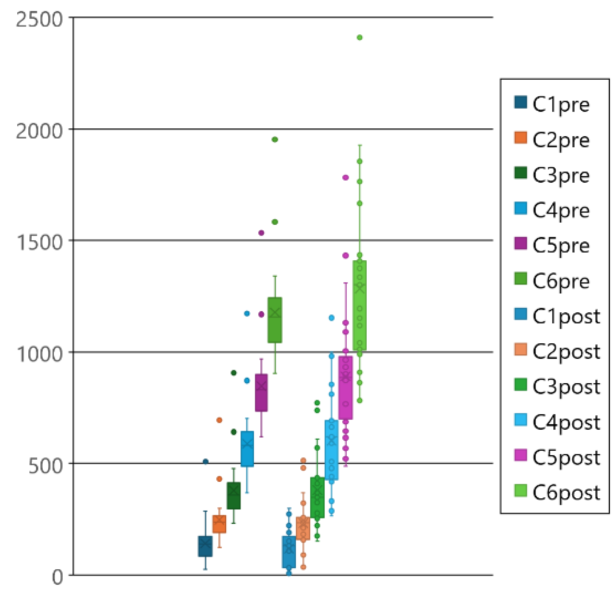

Figure 1: Comparison of apical (C1) to medial (C6) pre-operative and postoperative electrode contact positions of the cochlear implant as frequency [Hz] according to the organ of corti (not significantly different each). Same colors represent the same electrode contact (C1 = dark blue, C2 = orange, C3 = dark green, C4 = light blue, C5 = magenta, C6 = light green)

For these comparisons, we used the central electrode contact frequency. For the apical to medial electrode contacts C1 to C6, we found no significant difference (Shapiro-Wilk-Test: $p < 0.05$ each but C4 post-operatively with $p = 0.26$; Wilcoxon Signed-Rank Two-tailed Test for Paired Samples: $p\_exact > 0.05$ each). For the medial to basal C7, C8, and C9, we found a significant difference between pre-operative and post-operative values (Shapiro-Wilk-Test: $p < 0.05$ each; Wilcoxon Signed-Rank Two-tailed Test for Paired Samples: $p\_exact < 0.05$ each). For the basal contacts C10, C11, and C12, we

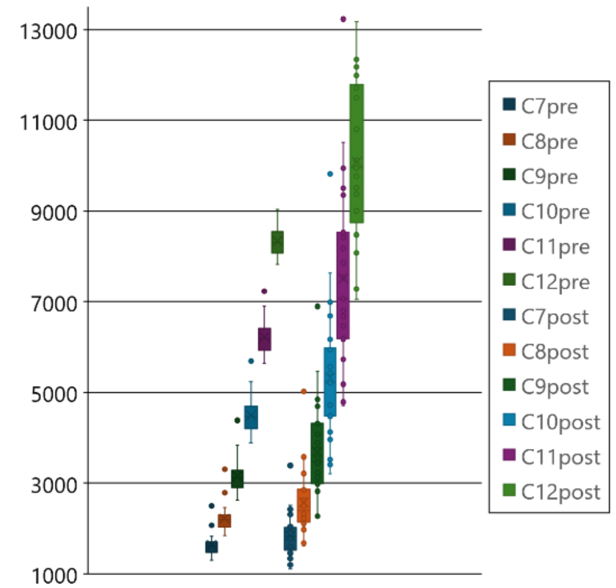

Figure 2: Comparison of medial (C7) to basal (C12) preoperative and postoperative electrode contact positions of the cochlear implant as frequency [Hz] according to the organ of corti (significantly different each). Same colors represent the same electrode contact (C7 = dark blue, C8 = orange, C9 = dark green, C10 = light blue, C11 = magenta, C12 = light green)

found a significant difference between preoperative and postoperative values (Shapiro-Wilk-Test: $p > 0.05$ each; Two-tailed T-Test for Paired Samples: $p < 0.05$ each). Alternatively, we compared pre- and postoperative evaluation by OTOPLAN in semitones instead of frequency differences in Hz (see **Figure 3**).

In 23 of our 27 study patients, the cochlear implant system has been activated (first fitting). A so-called 1m-control was done one month after the first fitting in fifteen patients. At the first fitting, seven patients had no tinnitus, five patients reported a tinnitus level I, nine reported level II, three reported level III, and no one reported level IV. Ten patients reported no dizziness or imbalance issues, ten reported a mild disorder, three reported a moderate disorder, and no one reported a severe disorder. At 1m-control, five patients reported no tinnitus, two patients reported level I, seven reported level II, one patient reported level III, and no one reported level IV. Six patients reported no dizziness or imbalance issues, six reported a mild disorder, four reported a moderate disorder, and no one reported a severe disorder. For tinnitus, we found no significant difference between preoperative, first fitting, and 1m-control (Shapiro-Wilk-Test (preop, first fitting, 1m-control): $p < 0.01$, 0.01, 0.01; Wilcoxon Signed-Rank Two-tailed Test for Paired Samples (preop vs. first fitting, preop vs.

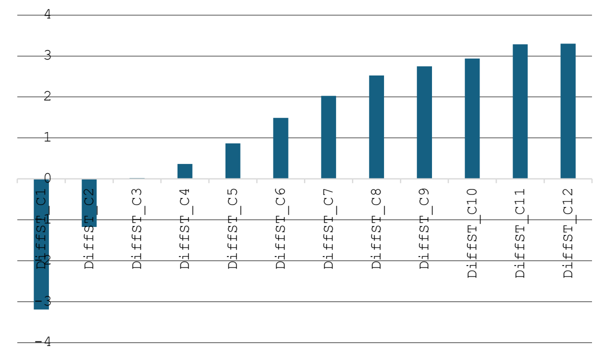

Figure 3: Comparison of apical (C1) to basal (C12) as difference between preoperative and postoperative electrode contact positions in semitones.

1m-control, first fitting vs. 1m-control): p_exact = 0.10, 0.16, resp. 1.00). For dizziness or imbalance issues, we found no significant difference between preoperative, first fitting, and 1m-control (Shapiro-Wilk-Test (preop, first fitting, 1m-control): $p < 0.01$, 0.01, 0.01; Wilcoxon Signed-Rank Two-tailed Test for Paired Samples (preop vs. first fitting, preop vs. 1m-control, first fitting vs. 1m-control): p_exact = 0.64, 0.38, resp. 1.00).

4 Discussion and conclusion

The aim of this study was to examine if any differences between anatomy-based fitting maps based on preoperative imaging (preopABF) and postoperative imaging (postopABF) can be observed.

In this study, we could show that there is no significant difference for the apical to medial (C1-C6) but a significant difference for medial to basal electrode contacts (C7-C12) between the preopABF and postopABF regarding the frequency bands. For the medial to basal electrode contacts (C7-C12), the higher frequencies respectively, the postopABF revealed a less deep insertion than estimated with the preopABF. For the apical to medial contacts (C1-C6), the lower frequencies respectively, although not significantly, the postopABF displayed a deeper insertion than estimated with the preopABF. This shows that for the preopABF OTOPLAN estimates that the electrode contacts are placed closer together than they are represented in the postopABF. This is also seen in the semitones evaluation: High frequencies should be perceived about 3 semitones higher, very low frequencies about 3 semitones lower in the postopABF. This is also in line with the results from a previous study, saying that frequency specific fitting of the basal electrode contact can be difficult with a normal insertion depth as it is often placed in a higher frequency range [10].

Regarding perioperative troubles like tinnitus and dizziness, we could not find a significant difference between preoperative and postoperative results. Generally, tinnitus burden is likely to decrease after cochlear implantation, which takes some time after the operation, tough, and can explain our results [11]. No exacerbation of vertigo after surgery could both be associated with a high quality of surgery and as well as the robotic-assisted insertion (RobOtol), which in another study showed significantly less vertigo in patient-reported outcomes than in the manual insertion [12].

The study has a few limitations. Firstly, we have a small number of patients. However, this is only a first pilot study. Secondly, we have a retrospective study design, which is, often the case when starting with pilot studies, tough. Thirdly, interpretation of the differences in frequencies has to be done with caution due to the logarithmic scaling on the human cochlear distribution. Thus we also evaluated the difference between pre- and postoperative data in semitones to better represent the potential subjective tone perception. How speech understanding is affected by the different center frequency values given by preopABF and postopABF in comparison is still to be investigated in homogeneous and also larger patient groups.

Concluding, the preopABF is an easy, clinically practicable way to implement ABF, which is promising to lead to better outcomes without extra costs and the radiation burden that comes with postopABF. If patients subjectively prefer either preopABF or postopABF is still to be examined.

Author Statement

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