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Electrode location and audiologic performance after cochlear implantation: a comparative study between Nucleus CI422 and CI512 electrode arrays

Brendan P. O'Connell, MD¹, Jacob B. Hunter, MD¹, Rene Gifford¹, Alejandro Rivas, MD¹, David S. Haynes¹, Jack H. Noble, PhD², and George B. Wanna, MD¹

¹Department of Otolaryngology-Head and Neck Surgery, Vanderbilt University, Nashville, TN 37232

²Department of Electrical Engineering and Computer Science, Vanderbilt University, Nashville, TN 37232.

Abstract

Objectives—1) Compare rates of scala tympani (ST) insertion between Nucleus CI422 Slim Straight electrodes and Nucleus CI512 Contour Advance electrodes; 2) examine audiometric performance with both electrode arrays, while controlling for electrode location.

Setting—Tertiary academic hospital.

Patients—56 post-lingually deafened adults undergoing cochlear implant (CI).

Main Outcome Measures—Primary outcome measures of interest were scalar electrode location and postoperative audiologic performance.

Results—Fifty-six implants in 49 patients were included; 20 were implanted with Nucleus CI422 Slim Straight electrodes and 36 were implanted with Nucleus CI512 Contour Advance electrodes. Overall, 62.5% (35/56) of implants had all electrodes located within the ST. Significantly higher rates of ST insertion (90%) were observed for Nucleus CI422 Slim Straight electrodes when compared to Nucleus CI512 Contour Advance electrodes (47.2%)($p=0.002$). In regards to audiologic performance, CNC scores were significantly higher for Nucleus CI422 Slim Straight electrodes (55.4%) compared to Nucleus CI512 Contour Advance electrodes (36.5%)($p=0.005$). In addition, AzBio scores were better for Nucleus CI422 Slim Straight electrodes (71.2%) when compared to Nucleus CI512 Contour Advance electrodes (46.7%)($p=0.004$). Controlling for ST insertion, higher AzBio scores were again observed for Nucleus CI422 Slim Straight electrodes ($p=0.02$).

CORRESPONDING AUTHOR: George B. Wanna, M.D., Department of Otolaryngology-Head and Neck Surgery, The Bill Wilkerson Center for Otolaryngology & Communication, Sciences 7209 Medical Center East, South Tower 1215 21st Avenue South, Nashville, Tennessee 37232-8605, Telephone: 615-322-6180, Fax: 615-343-9725, george.wanna@vanderbilt.edu.

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Conclusions—The results of this study demonstrate that the Nucleus CI422 Slim Straight electrode is more likely to reside entirely within the ST when compared to the Nucleus CI512 Contour Advance electrode. Furthermore, AzBio scores were superior for patients with Nucleus CI422 Slim Straight electrodes in all patients, as well as those with only ST insertions.

INTRODUCTION

A growing body of evidence supports the notion that preservation of intracochlear structures impacts post-operative cochlear implant(CI) performance. Specifically, better speech perception has been observed for electrodes residing entirely within the scala tympani(ST).¹⁻³ In addition, maintaining residual hearing is more common in patients with ST insertions compared to those with electrode contacts in the scala vestibuli(SV).⁴ Given these findings, the impact of electrode design on intracochlear electrode location has been investigated, with lateral wall electrodes translocating into the SV less frequently than perimodiolar electrodes.^{1,5}

Cochlear Americas(Sydney, Australia) offers both lateral wall(Nucleus CI422 Slim Straight) and precurved perimodiolar(Nucleus CI512 Contour Advance) electrode designs; studies examining CI location *in vivo* and subsequent performance with these electrodes are lacking. Given the different electrode designs, the primary objectives of the current study were: 1) compare rates of ST insertion between Nucleus CI422 Slim Straight(CI422) and Nucleus CI512 Contour Advance(CI512) electrodes, 2) examine postoperative audiometric performance with both devices controlling for electrode location.

MATERIALS AND METHODS

Patient Selection and Clinical Information

Institutional review board approval was obtained. Post-lingually deafened adults undergoing CI over a 5 year period(November 2009 to December 2014) were eligible for inclusion. We retrospectively reviewed a prospectively acquired database, and selected patients that underwent CI with either a CI422 electrode or CI512 electrode. Consenting patients underwent preoperative and postoperative temporal bone computed tomography(CT) such that electrode location could be determined. If information regarding electrode location was unavailable, the patient was excluded from the study.

Patient demographics(age, gender, race) and type of electrode(CI422 vs. CI512) were recorded. The presence of functional residual hearing at the time of CI was noted, and defined as an air conduction threshold ≤ 80 dB at 250 Hz. Post-operative hearing preservation, defined as an air conduction threshold ≤ 80 dB at 250 Hz, was examined using the first post-operative audiogram in which air conduction thresholds were measured.

Outcome Measures: Angular Insertion Depth, CI Location and Speech Perception

Outcome measures included angular insertion depth(AID), scalar electrode location and audiologic performance. Angular insertion depth was measured as the maximum angular depth of all of the contacts using the coordinate system defined by Verbist et al.⁶

Methodology for radiographically determining electrode location in relation to ST and SV has been previously reported.^{1,7-9} Briefly, an active shape model is used to identify the ST and SV on a pre-operative CT. The post-operative CT scan allows for identification of each electrode contact using either semi-automated or fully automated approaches. The post-operative CT scan is rigidly fused to the pre-operative scan, and the scalar location of each electrode contact can be determined. This approach has been validated using cadaveric models.¹⁰ For convention in this report, electrode arrays with any contact in the SV were termed SV insertion. Conversely, if all intracochlear electrode contacts were located outside of the SV, the insertion was characterized as a ST insertion.

Speech perception was assessed between 6-18 months post-operatively. Consonant-nucleus-consonant(CNC) word scores and AzBio sentence scores obtained at the time point closest to 1 year post-operatively were recorded. All patients were tested in quiet, in the CI only condition.

Statistical Analysis

Fisher's exact test, chi-square tests, two-tailed t-tests, and Mann-Whitney tests were used to compare parametric and non-parametric continuous data, as appropriate. Pearson or Spearman tests were performed to assess correlations of parametric and non-parametric variables. All analyses were performed with GraphPad Prism 6.0(GraphPad Software, Inc., La Jolla, CA).

RESULTS

Demographics and Clinical Characteristics

The 49 patients (56 implants) included were predominantly male(59.2%), Caucasian(93.8%), and had a mean age at the time of CI of 62.7 years. Of the 56 implants, 20(35.7%) electrodes were CI422 and 36(64.3%) electrodes were CI512. As shown in **Table 1**, no differences between the CI groups were noted in relation to gender($p=0.24$), race($p=0.29$), pre-operative residual hearing($p=0.18$), age at the time of CI($p=0.17$), or post-operative hearing preservation($p=0.29$). Two patients lacked preoperative thresholds at 250 Hz; 8 patients lacked post-operative thresholds at 250 Hz.

Electrode Location

Overall, 62.5%(35/56) of implants had all electrodes located within the ST. As shown in **Figure 1**, significantly higher rates of ST insertion(90%) were observed for CI422 electrodes when compared to CI512 electrodes(47.2%)($p=0.002$). Mean AID of CI422 electrodes ($410.5^\circ \pm 77.6$, range 282-585) did not differ significantly when compared to CI512 electrodes ($380.5^\circ \pm 44.5$, range 279-474)($p=0.07$). AID did not differ between ST insertions($386.1^\circ \pm 66.6$) and SV insertions($399.7^\circ \pm 45.9$)($p=0.41$).

Audiologic Performance

Audiologic outcomes were assessed 6-18 months(mean 11.8 ± 2.4 months) postoperatively. AzBio scores were available for 41 cases with a mean score of $58.9\% \pm 27.5$. AzBio scores were superior for CI422 electrodes($71.2\% \pm 19.8$) as compared to CI512 electrodes(46.7%

± 28.8)($p=0.004$) (**Figure 2**). Given that higher rates of ST insertion were noted with CI422 electrodes, AzBio scores were then examined for electrode arrays positioned entirely within the ST. Controlling for ST insertion, superior performance was again observed for CI422 electrodes($70.0\% \pm 19.7$) when compared to CI512 electrodes($46.0\% \pm 32.2$)($p=0.02$). A correlation between AID and AzBio score was noted for CI422 electrodes ($r=0.55$, $p=0.01$); no correlation was present in the CI512 group ($r=0.08$, $p=0.72$).

CNC scores were available for 47 implants with a mean postoperative score of $43.9\% \pm 22.9$. CNC scores were significantly higher for CI422 electrodes($55.4\% \pm 17.6$) when compared to CI512 electrodes($36.5\% \pm 23.6$)($p=0.005$) (**Figure 2**). Similar trends were noted when controlling for electrodes located entirely in the ST, but a significant difference between CI422($55.6\% \pm 16.2$) and CI522($43.9\% \pm 30.2$) groups was not present($p=0.18$). A significant correlation was observed between AID and CNC score for CI422 electrodes($r=0.57$, $p=0.01$)(**Figure 3**), but not CI512($r=0.04$, $p=0.83$).

The impact of age, pre-operative residual hearing, and post-operative residual hearing on speech perception was assessed. No significant associations were observed($p>0.15$ for all analyses).

DISCUSSION

Using a previously validated active-shape statistical model to delineate intracochlear anatomy on CT imaging, we are able to determine the scalar position of electrode arrays *in vivo* and thus examine audiologic outcomes in relation to both electrode location and design. In this report, CI location and speech perception were compared for a lateral wall electrode(CI422) and a perimodiolar electrode(CI512).

Our data demonstrate that higher rates of ST insertion were achieved with CI422 electrodes when compared to CI512 electrodes. Specifically, the vast majority(90%) of CI422 arrays had all electrode contacts positioned within the ST, while ST insertion was achieved in roughly half(47%) of CI512 implants. These results corroborate prior studies which demonstrate that higher rates of ST insertion are observed with lateral wall electrodes when compared to perimodiolar electrodes.^{1,5} The most likely explanation for this finding is that the flexible mechanical properties of lateral wall electrodes decreases the likelihood that translocation from the ST into the SV will occur.

We also sought to examine speech perception performance and found that in the entire cohort, patients with CI422 electrodes performed significantly better on CNC and AzBio testing at 1 year post-operatively when compared to those with CI512 electrodes. Studies have suggested that increasing cochlear coverage by extending electrodes into the apical region reduces the need for cortical remapping and results in superior performance post-operatively.¹¹⁻¹³ Our findings support this notion, as CI422 electrodes tended to have greater AID than 512 electrodes, although this difference did not reach significance. Further, a direct relation between depth of insertion and speech understanding was observed within the CI422 group. It should also be noted that greater depths of insertion were not associated with higher rates of electrode translocation into the SV.

As mounting evidence suggests that ST insertions are associated with better post-operative audiologic performance, we controlled for scalar location and performed further subset analysis of speech perception in relation to electrode design. Similar to findings in the entire cohort, AzBio scores were also significantly better with CI422 electrodes compared to CI512 electrodes, although differences in CNC scores did not reach statistical significance.

This study has limitations that warrant discussion. Despite prospective accrual of patients, clinical information was recorded retrospectively, therefore not all variables could be controlled. Not all patients implanted with CI422 and CI512 electrodes at our institution met inclusion criteria, therefore there is also potential for selection bias. It should be noted that mean CNC score within the CI512 group is less than what is generally reported for this electrode; this may be due to selection bias and further studies comparing audiologic outcomes of straight arrays to perimodiolar arrays are needed. While differences in pre-operative and post-operative hearing may also confound results, we found no differences in these measures between groups. Further, neither pre-operative residual hearing nor post-operative hearing preservation were independently associated with outcomes, therefore are unlikely to impact the reported results. Because of the sample size of patients in each group, there is a higher probability of type II error.

CONCLUSION

The results of this study demonstrate that the CI422 electrode is more likely to reside entirely within the ST when compared to the CI512 electrode. Furthermore, AzBio scores were superior for patients with Nucleus CI422 Slim Straight electrodes in all patients, as well as those with only ST insertions.

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IRB APPROVAL: This study was approved by the Vanderbilt IRB #090155.

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Figure 1.

The number of implants achieving either a scala tympani or scala vestibuli insertion is depicted here. Higher rates of scala tympani insertion were noted with CI422 electrode arrays ($p=0.002$).

Figure 2.

AzBio scores and CNC scores at 1 year post-implant were higher for CI422 electrodes than CI512 electrodes (p=0.004 and p=0.005, respectively).

Figure 3.

A positive correlation between AID and CNC score was noted for CI422 electrode arrays.

Table 1

Comparisons of demographic features, pre-operative residual hearing, and immediate post-operating hearing preservation rates between Nucleus CI422 Slim Straight and Nucleus CI512 Contour Advance groups. No differences were noted between groups.

	CI422 Slim Straight N= 20	CI512 Contour Advance N=36	p value
	Mean $\pm$ SD	Mean $\pm$ SD	
Age	63.2 $\pm$ 15.5	59.8 $\pm$ 14.1	0.17
	n (%)	n (%)	
Gender			
Male	14 (70.0%)	18 (50.0%)	0.24
Female	6 (30.0%)	18 (50.0%)	
Race			
Caucasian	20 (100.0%)	32 (88.9%)	0.29
Other	0 (0%)	4 (11.1%)	
Preop Residual Hearing			
Yes ($\leq$ 80 dB at 250 Hz)	14 (70.0%)	16 (47.1%)	0.18
No (>80 dB at 250 Hz)	6 (30.0%)	18 (52.9%)	
Postop Hearing Preservation			
Yes ($\leq$ 80 dB at 250 Hz)	3 (15.8%)	1 (3.4%)	0.29
No (>80 dB at 250 Hz)	16 (84.2%)	28 (96.6%)	