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Predictive factors for short- and long term hearing preservation in cochlear implantation with conventional length electrodes

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Abstract

Objectives—1) Investigate short- and long-term rates of hearing preservation after cochlear implantation, and 2) identify factors that impact hearing preservation.

Study Design—Retrospective review

Methods—Patients undergoing cochlear implantation with conventional length electrodes and air-conduction thresholds ≤80 dB HL at 250 Hz pre-operatively were included. Hearing preservation was defined as air-conduction thresholds ≤80 dB HL at 250 Hz.

Results—The sample included 196 patients (225 implants). Overall, the rate of short-term hearing preservation was 38% (84/225), with 18% (33/188) of patients preserving hearing long-term. Multivariate analysis showed better pre-operative hearing was predictive of hearing preservation at short (OR 0.93, 95%CI 0.91–0.95, p<0.001) and long-term follow-up (OR 0.94, 95%CI 0.91–0.97, p<0.001). Lateral wall electrodes and mid-scala electrodes had 3.4 (95%CI 1.4–8.6, p=0.009) and 5.6-times (95%CI 1.8–17.3, p=0.003) higher odds of hearing preservation than perimodiolar arrays at short-term follow-up, respectively. Long-term data revealed better hearing preservation for lateral wall (OR 7.6, 95% CI 1.6–36.1, p=0.01), but not mid-scala (OR 3.1, 95%CI 0.4–23.1, p=0.28), when compared to perimodiolar electrodes. Round window/extended round window (RW/ERW) approaches were associated with higher rates of long-term hearing preservation (18%) than cochleostomy approaches (0%)(p=0.004) on univariate analysis.

Conclusions—Better pre-operative residual hearing, lateral wall electrodes, and RW/ERW approaches are predictive of higher rates of long-term functional hearing preservation.

Keywords

cochlear implant; hearing preservation; electrode design; surgical approach

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INTRODUCTION

Cochlear implantation remains the standard of care for hearing rehabilitation in patients with severe-to-profound sensorineural hearing loss. Indications for implantation have expanded to include patients with moderate sloping to profound sensorineural hearing loss for conventional implantation, and those with even greater degrees of residual hearing for electric-acoustic stimulation (EAS) systems. Preservation of low-frequency hearing allows cochlear implant (CI) users access to both electrical and acoustic hearing. Recent studies have demonstrated that EAS confers performance benefit with regard to speech understanding in complex listening environments, music perception, and localization.[1–5] As a result, minimally traumatic surgery and hearing preservation have become fundamental concepts of CI surgery.

Despite advances in electrode design and increased surgical experience with minimally traumatic techniques, residual hearing is still lost in a considerable number of patients.[6] Various groups have attempted to identify factors that impact hearing preservation, with surgical approach, electrode design, insertion depth, scalar electrode position, age, and inflammation being identified as potentially important factors.[7–10] Interpreting the relative importance of these variables is challenging due to significant heterogeneity amongst studies in how hearing preservation is defined. To this end, the authors assert that maintenance of functional hearing—hearing that can be successfully aided acoustically—should be the most important consideration in reporting hearing preservation outcomes. Thus, the primary objectives of the current study were: 1) investigate short- and long-term rates of functional hearing preservation in patients undergoing CI with conventional length electrodes, and 2) examine factors that impact functional hearing preservation rates immediately post-implant, as well as longitudinally.

MATERIALS AND METHODS

Patient Selection

Post-lingually deafened adult CI patients were identified at a single tertiary otologic referral center over a five-year period (2011–2015). Inclusion criteria were: 1) unaided pre-operative air-conduction thresholds ≤80 dB HL at 250 Hz in the ear to be implanted, 2) post-operative air-conduction thresholds were obtained in the audiology clinic, and 3) implantation with conventional length electrode arrays. Excluded from the analysis were recipients of a Hybrid-L24 implant or those with a documented history of prior neurotologic surgery, meningitis, Meniere’s disease, autoimmune inner ear disease or other autoimmune pathology, superior semicircular canal dehiscence, traumatic temporal bone fracture, or devices that were explanted.

Demographics and Operative Characteristics

Prospectively collected information regarding patient demographics, type of electrode (perimodiolar, lateral wall, mid-scala), and surgical approach (cochleostomy, round window [RW] or extended round window [ERW]) were reviewed. All devices were implanted through a post-auricular facial recess approach. Minimally traumatic surgical techniques have been used at our institution since the initial data collection for this study. RW and ERW approaches were grouped together, as prior studies have suggested the two approaches do not differ significantly in regard to scalar traumatization.[11] Medical charts were reviewed for a history of diabetes mellitus and the use of post-operative oral steroids.

Audiometric Data- Functional Hearing

Successful hearing preservation was defined as a post-operative air-conduction threshold ≤80 dB HL at 250 Hz. This threshold criterion was chosen since the target gain with acoustic amplification is theoretically achievable when figuring a half-gain rule for acoustic amplification and typical low-frequency gain limits for conventional hearing aids in the range of 40 to 45 dB. 250 Hz was chosen for two reasons: 1) it is the lowest frequency for which we are able to verify hearing aid output for various prescriptive fitting targets, thus serving as a marker for whether or not residual hearing is *functionally useful*, and 2) acoustic hearing low-pass filtered at 250 Hz is the minimum bandwidth for which significant additive EAS benefit is observed for CI recipients in either the non-implanted or the implanted ear.[12–15] Short-term outcomes are reported using the first available audiogram after implantation, which was typically performed at activation 2–3 weeks post-operatively. Long-term outcomes are reported using the most recent audiogram with available air-conduction thresholds in the unaided condition, obtained at least 1 year post-activation.

Patients who lost residual hearing rarely underwent further unaided testing, therefore these cases were included in longer-term analyses as hearing preservation failures. Patients who preserved hearing, but lacked follow-up beyond 1 year post-operatively, were excluded from the long-term analysis. Long-term intent-to-treat multivariate analysis was also performed to minimize the bias of loss to follow-up. To be conservative with our estimates in this analysis, the subset of patients with preserved short-term hearing, but no long-term follow-up, were assumed to ultimately have lost hearing.

Audiometric Data- Low-Frequency Pure-Tone Average

Low-frequency PTA was calculated using the average of unaided air-conduction thresholds at 125, 250, and 500 Hz. Variables that impact PTA shift from pre-operative to the time of last audiometric follow-up were analyzed.

Statistical Analysis

Univariate analyses were performed to assess the relationships between outcome measures (≤80 dB HL at 250 Hz and low-frequency PTA shift) and the following variables: age, gender, race, electrode design, surgical approach, post-operative oral steroid use, and diabetes. Fisher's exact test, chi-square tests, two-tailed t-tests, Mann-Whitney tests, and ANOVA with post-hoc multiple comparisons tests were used to compare parametric and non-parametric categorical and continuous data, as appropriate. Multivariate logistic regression was performed to identify independent predictors of short- and long-term hearing preservation and low-frequency PTA shift. Covariates were included in multivariate models if the $p<0.20$ on univariate comparisons. Analyses were performed with STATA 12MP (StataCorp LP, College Station, TX).

RESULTS

Demographics and Operative Characteristics

The final sample included 196 patients (225 implants) whom were predominantly male (56.4%) and Caucasian (97.0%). The mean age at the time of CI was 63.7 years (range of 18–89 years). Round window approaches were implemented in 84.4% of cases while 15.6% patients underwent insertion via a cochleostomy. Proportions of implanted electrode arrays were 60.0% lateral wall, 24.4% perimodiolar, and 15.6% mid-scala (Table 1).

Hearing Preservation Changes over Time

The majority of patients (84%) demonstrated some measurable unaided air-conduction thresholds at activation. However, the rate of *functional* short-term hearing preservation was 38% (84/225). Data from 188 implants were available for one-year post-activation analyses, as 37 had been lost to follow-up. At a minimum of 1-year post-activation (mean 19 months), 18% (33/188) of patients preserved functional hearing.

Predictors of Short-term Hearing Preservation

Univariate analyses of covariate associations with short-term hearing preservation are shown in Table 2. Pre-operative air-conduction thresholds at 250 Hz were significantly lower in the hearing preservation group (p<0.0001). Higher rates of hearing preservation were observed with lateral wall (43%) and mid-scala electrodes (48.5%) as compared to perimodiolar (10.9%) arrays (p=0.004 and 0.002, respectively). With respect to surgical approach, 40.5% of RW/ERW procedures preserved hearing compared to 20% of those inserted via a cochleostomy approach (p=0.03). Patients without diabetes were more likely to exhibit preserved hearing (40.9%) when compared to diabetics (20.5%)(p=0.03). Demographic variables and post-operative oral steroid use did not correlate with short-term hearing preservation.

Multivariate logistic regression of short-term outcomes showed a lower air-conduction threshold at 250 Hz pre-operatively was independently associated with higher rates of functional hearing preservation post-operatively (OR [odds ratio] 0.93, 95% CI 0.91–0.95, p<0.001) (Table 3 and Figure 1). Electrode design was also independently predictive of short-term hearing preservation. Specifically, lateral wall and mid-scala electrodes were associated with 3.4 (95% CI 1.4 – 8.6, p=0.009) and 5.6 (95% CI 1.8 – 17.3, p=0.003) times higher odds of hearing preservation when compared to perimodiolar arrays, respectively. Surgical approach, diabetes, and post-operative oral steroid use were not associated with short-term hearing preservation.

Predictors of Long-term Hearing Preservation

Univariate analyses of covariate associations with long-term hearing preservation are shown in Table 4. Pre-operative air-conduction thresholds at 250 Hz were significantly lower in the hearing preservation cohort (p<0.0001). Higher rates of hearing preservation were observed with lateral wall (25.7%) when compared to perimodiolar (3.9%) arrays (p=0.0008)(Figure 2). No significant differences in hearing preservation rates were noted when comparing mid-scala (10.7%) electrodes to lateral wall or perimodiolar arrays (p=0.12 and p=0.34, respectively). RW/ERW procedures were associated with significantly higher rates of long-term hearing preservation (18%) when compared to cochleostomy procedures (0%) (p=0.004). Patients treated with post-operative oral steroids were also more likely to demonstrate hearing preservation (28.8%) when compared those not treated with post-operative oral steroids (10.4%)(p=0.003).

Multivariate logistic regression analysis was performed (Table 5). Pre-operative hearing thresholds at 250 Hz and electrode array were again independently predictive of higher rates of long-term hearing preservation. In regard to electrode design, lateral wall electrodes had 7.6 times higher odds of maintaining functional hearing (OR 7.6, 95% CI 1.6–36.1, p=0.01) than perimodiolar arrays. While the mid-scala design was protective of hearing preservation at short-term when compared to perimodiolar arrays, similar benefit was not observed long-term (OR 3.1, 95% CI 0.4–23.1, p=0.28). Post-operative oral steroids were associated with better long-term hearing preservation (OR 3.2, 95% CI 1.3–8.0, p=0.01). Intent to treat analysis was performed and independent predictors were unchanged.

Low-frequency Pure-Tone Average Shift

The median pre-operative low-frequency PTA was 63 dB HL (range 17–88). Median low-frequency PTA at activation was 88 dB HL (range 42–110), and 97 dB HL (range 37–110) at the time of last audiometric follow-up (mean 11 months). In univariate analysis, PTA shift at last follow-up was not significantly associated with gender, diabetes, or post-operative oral steroid use (p>0.05). Mean PTA shifts for lateral wall (27 dB) and mid-scala electrodes (26 dB) were significantly less than perimodiolar electrodes (34 dB)(p=0.04 for both analyses); no difference between lateral wall and mid-scala was apparent (p=0.55). Higher PTA shifts were noted for cochleostomy approaches (34 dB) when compared to RW/ERW approaches (28 dB)(p=0.04). PTA shift also correlated with age at implantation (r=0.16, p=0.02) and pre-operative low-frequency PTA (r=−0.40, p<0.0001).

Multivariate linear regression analysis was performed (Table 6). Use of lateral wall electrodes was associated with a 7 dB decrease in low-frequency PTA shift when compared to perimodiolar electrodes. Further, cochleostomy approaches were associated with a 6 dB increase in low-frequency PTA shift when compared to RW/ERW approaches.

DISCUSSION

This study was designed to assess hearing preservation in a large cohort (n=225) undergoing CI with conventional length electrodes. The short- and long-term rates of *functional* hearing preservation were 38% and 18%, respectively. At short-term follow-up, lower pre-operative air-conduction thresholds at 250 Hz and the use of either lateral wall or mid-scala electrodes conferred higher rates of hearing preservation. When assessed at least 1-year post-activation, degree of pre-operative hearing loss, use of lateral wall electrodes, and administration of post-operative oral steroids were independently predictive of better hearing preservation via multivariate analysis. RW/ERW approaches were associated with better long-term hearing preservation in univariate analysis. When lateral wall electrodes and round window approaches were used, short- and long-term hearing preservation rates were 47% and 30%, respectively.

Analysis of variables that impact PTA shift mostly corroborate the aforementioned findings – lateral walls electrodes and RW/ERW approaches were associated with lower PTA shift (i.e. better hearing preservation) when compared to perimodiolar arrays and cochleostomy approaches. The use of oral steroids, however, was not predictive of PTA shift.

Hearing Preservation Rates

Maintenance of functional hearing should be the main objective of hearing preservation surgery, as this allows for use of EAS. Therefore, we chose to define hearing preservation as unaided air-conduction thresholds ≤80 dB HL at 250 Hz, with this being the upper limit of the maximum low-frequency amplification with current hearing aids.[13–15] Using this metric, our data demonstrate that 38% of all conventional CI recipients with residual hearing will maintain functional hearing at the time of activation.

Currently, there is a significant heterogeneity in regard to how hearing preservation is defined which results in a wide range of hearing preservation rates cited in the relevant literature. Differences in methodology must be considered when comparing findings between studies. If hearing preservation is defined as the presence of measurable thresholds post-operatively, it is not surprising that short-term hearing preservation rates in other studies are considerably higher (47–100%) than that reported herein for *functional* hearing preservation.[16–20] Eighty-four percent of the patients in this study had measurable thresholds at activation. We recognize that there are limitations to our definition of hearing preservation, which dichotomizes outcomes based on thresholds at a single frequency. That being said, we think that applying stringent criteria as to whether hearing is truly aidable, based on both scientific evidence for useful EAS and clinical applicability of low-frequency amplification, provides the most clinically relevant information.

Data pertaining to long-term hearing preservation are limited. One must again interpret available data in the context of study methodology. Dedhia et al. report long-term hearing preservation in 94% of patients with immediate post-operative hearing preservation.[21] However, roughly 30% of patients had follow-up less than 1 year, and hearing preservation was defined as the presence of measurable thresholds. In patients with at least 2 years follow-up, Jurawitz et al. demonstrated that 28.6% of patients implanted with a conventional length electrode had a mean pure-tone average threshold shift ≤15 dB.[22] Regardless of the methodology used to define hearing preservation, most studies demonstrate that residual hearing deteriorates with time, at a rate greater than that can be expected with natural progression of disease.[16,22–24] Our findings corroborate this notion, in that only 18% of patients had functional residual hearing at least 1 year post-activation. When analyzing patients implanted with lateral wall array via round window approaches, the long-term hearing preservation rate increases to 30%. This has significant implications for counseling, as the majority of patients did not have aidable low-frequency hearing beyond 1 year.

Factors Predictive of Hearing Preservation

Despite extensive research, factors predictive of preserving residual hearing remain unclear. Electrode design, surgical approach, and inflammation have all been implicated as potentially important variables. To address the relative impact of these variables, we approached this issue from a single institution with a large number of CI recipients, which enabled us to apply a strict standardized definition of functional hearing preservation and implement multivariate analyses.

The present data set comprises a diverse sample of patients; as such differing degrees of pre-operative residual hearing were present within the cohort. Not surprisingly, better pre-operative air-conduction thresholds were associated with higher rates of post-operative hearing preservation at both short- and long-term follow-up. Although intuitive, this has clinical implications in that patients with borderline functional hearing pre-operatively should be counseled that there is high likelihood they will not have access to acoustic hearing post-operatively in the implanted ear. Another potential implication is that patients who exhibit poorer hearing pre-operatively (borderline functional), and therefore a lessened chance of hearing preservation, may benefit from a longer electrode array to maximize cochlear coverage and speech perception performance.[25–27] Given the number of patients included in this report, we were able to control for degree of pre-operative hearing loss when analyzing the impact of other covariates in regression analyses.

Electrode design was found to be an independent predictor of hearing preservation at short- and long-term follow-up. While hearing preservation was possible with all electrode types, rates of preservation differed significantly according to design. Specifically, at short-term follow-up, lateral wall and mid-scala electrodes were 3.4 and 5.6 times more likely to preserve functional hearing when compared to perimodiolar electrodes. The majority of available data show that lateral wall electrodes enter the scala vestibuli much less frequently than perimodiolar electrode arrays.[11,28,29] Data regarding scalar location of mid-scala implants are more limited. While cadaveric studies suggest that the vast majority of electrode arrays ultimately are positioned entirely within the scala tympani, *in vivo* data suggest lower rates (43%) of scala tympani placement.[11,30,31] When compared to perimodiolar arrays long-term, lateral wall electrodes were again independently predictive of functional hearing preservation, but mid-scala arrays were not.

The role of surgical approach in cochlear implantation remains a controversial topic. The majority of clinical studies have found no differences in short-term hearing preservation rates in relation to approach.[32,33] While a recent systematic review comparing approaches also failed to demonstrate differences between approaches, a meta-analysis suggested that cochleostomy approaches were associated with higher rates of hearing preservation than RW approaches.[34,35] In contrast, other groups have demonstrated worse hearing preservation with cochleostomy approaches.[36]

The long-term impact that surgical approach has on hearing preservation rates is even less clear. In the present report, we found that rates of longer-term hearing preservation were better RW/ERW approaches (18%) than cochleostomy (0%) approaches on univariate analysis. Further, multivariate linear regression demonstrated the use of a cochleostomy was associated with a PTA shift 6 dB greater (i.e. worse hearing preservation) than that observed for RW/ERW approaches. The most likely explanation for this finding is that a cochleostomy results in trauma at the insertion site that incites delayed tissue formation and/or ossification that adversely impact longer-term hearing outcomes. Animal studies support this notion in that RW insertions have been shown to result in less tissue formation, which correlated with better hearing outcomes.[37] Post-mortem temporal bone studies demonstrated that cochleostomy approaches were more likely to result in scala vestibuli fibrosis and endolymphatic hydrops when compared RW insertions.[38] The authors hypothesized that cochleostomies involving the scala vestibuli result in fibrosis of cochlear scala, leading to endolymphatic hydrops which may be responsible for delayed hearing loss after CI. In support of this theory, Quesnel et al. described a patient who experienced delayed loss of residual hearing, and was found to have intrascalar fibrous tissue and new bone formation years after a cochleostomy approach.[39] Taken together, there appears to be sufficient data to support the use of a RW/ERW approach to maximize chances of long-term hearing preservation, and thus should be the approach of choice for a CI patient with residual hearing.

The use of steroids administered either systemically or topically has been studied fairly extensively, yet no evidence driven consensus on the dosage or route of administration has been reached. In this study, all patients received a one-time dose of intravenous steroids at induction of anesthesia. The use of post-operative systemic steroids varied according to surgeon and was therefore studied; our findings were conflicting according to outcome measure of interest. While prescription of oral steroids was protective of long-term functional hearing preservation, no relationship between steroids and PTA shift was noted. A recent meta-analysis demonstrated a protective effect for post-operative systemic steroids, although determining the temporal effect with such a study design presented challenges.[35] It is possible that post-operative systemic steroids attenuate inflammation after electrode insertion and protect against loss of residual hearing, but further studies in this regard are needed.[40]

Lastly, neither age nor gender was found to impact short- or long-term functional hearing preservation. No consensus exists in current literature regarding the impact of age on hearing preservation in adults; however, preservation in children and adolescents generally seems more favorable than in adults.[20,36,41–43] Kopelovich et al. studied 85 adults who received Hybrid electrode arrays and found that younger age and female gender were associated with better long-term hearing preservation.[43] Further, Anagiotos et al. and Cosetti et al. both reported that hearing preservation correlated with younger age in patients implanted with conventional length electrodes.[20,42] In contrast to these studies, Eshraghi et al. did not find a significant relationship between either age or gender and loss of residual hearing; patients of all ages were included in this report.[36] Zanetti et al. also failed to demonstrate a significant association between age and hearing preservation.[41] Further study is needed in this regard; only adults undergoing implantation with conventional length electrodes were included herein, which limits our ability to fully assess the impact of age on hearing preservation.

Limitations

Given the retrospective design, we could not assess all variables that may impact hearing preservation. Such variables include speed of insertion, scalar location of electrodes, and angular insertion depth. Further, while soft surgical techniques have been employed at our institution throughout the entirety of the study duration, it is not possible to retrospectively control for differences in surgical technique on a case-to-case basis. Given the fact that patients were not randomized to electrode type or surgical approach, the study is subject to selection bias. In regard to electrode type, multivariate analysis controlled for pre-operative hearing thereby minimizing this bias. In regard to surgical approach, the current practice at our institution is that we intend to place electrodes via RW approaches, if intraoperative anatomical findings suggest this is not the appropriate approach, we revert to either an ERW insertion or a minimally invasive cochleostomy. As a high volume implant center, many cochleostomy approaches have been performed therefore inexperience with this surgical approach is unlikely to impact results. Lastly, it should be noted that a number of patients were lost to follow-up, and the data reported herein may be an underestimation of hearing preservation rates.

CONCLUSION

Pre-operative hearing status, lateral wall electrode design, and RW/ERW approaches were associated with better functional hearing preservation long-term. When lateral wall electrodes and RW/ERW approaches were used, air conduction thresholds ≤80 dB HL at 250 Hz were achieved in 47% of patients at activation, and 30% of patients beyond 1 year post-operatively.

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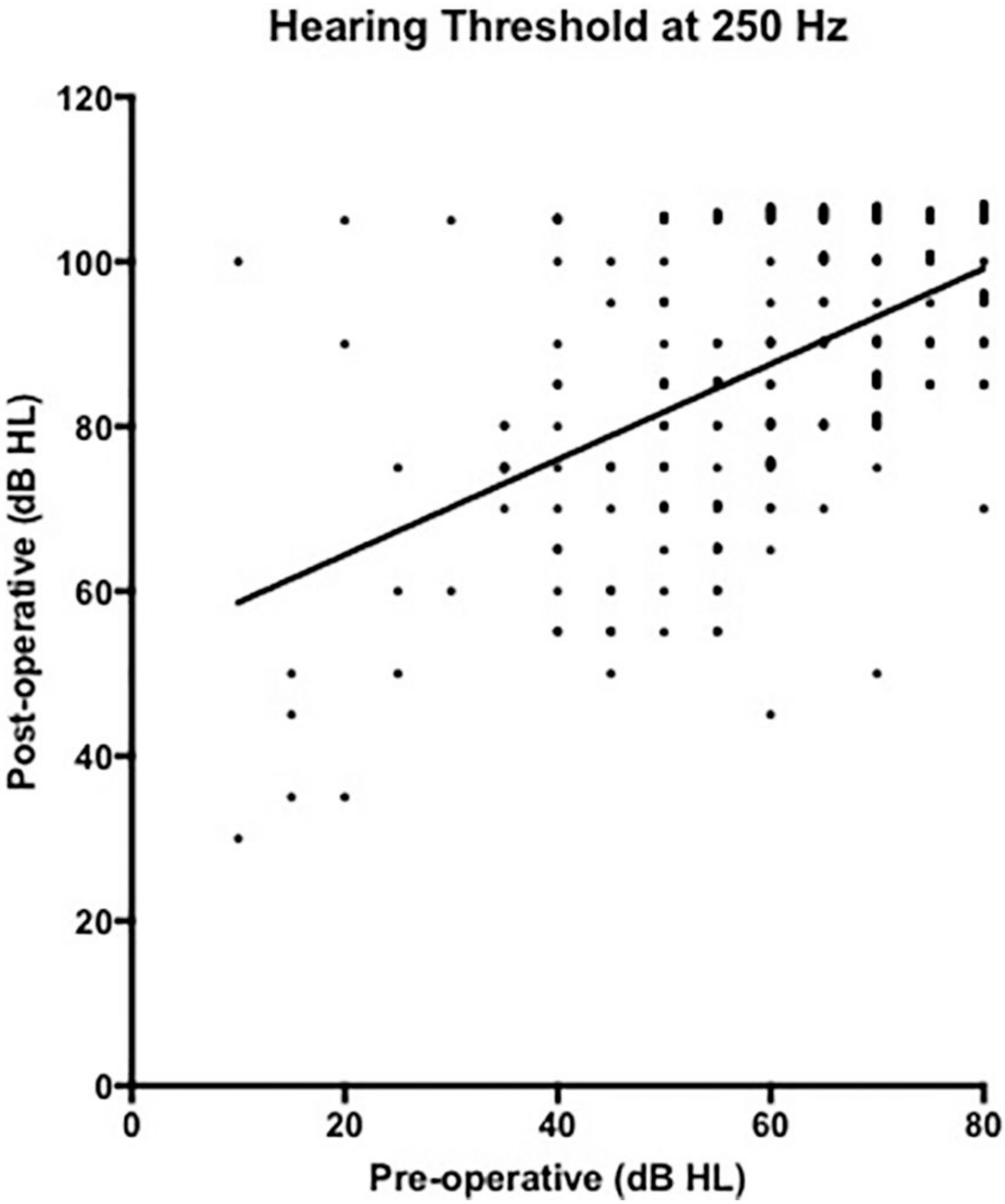

Figure 1.
Relationship between pre- and post-operative unaided air-conduction thresholds, in dB HL at 250 Hz.

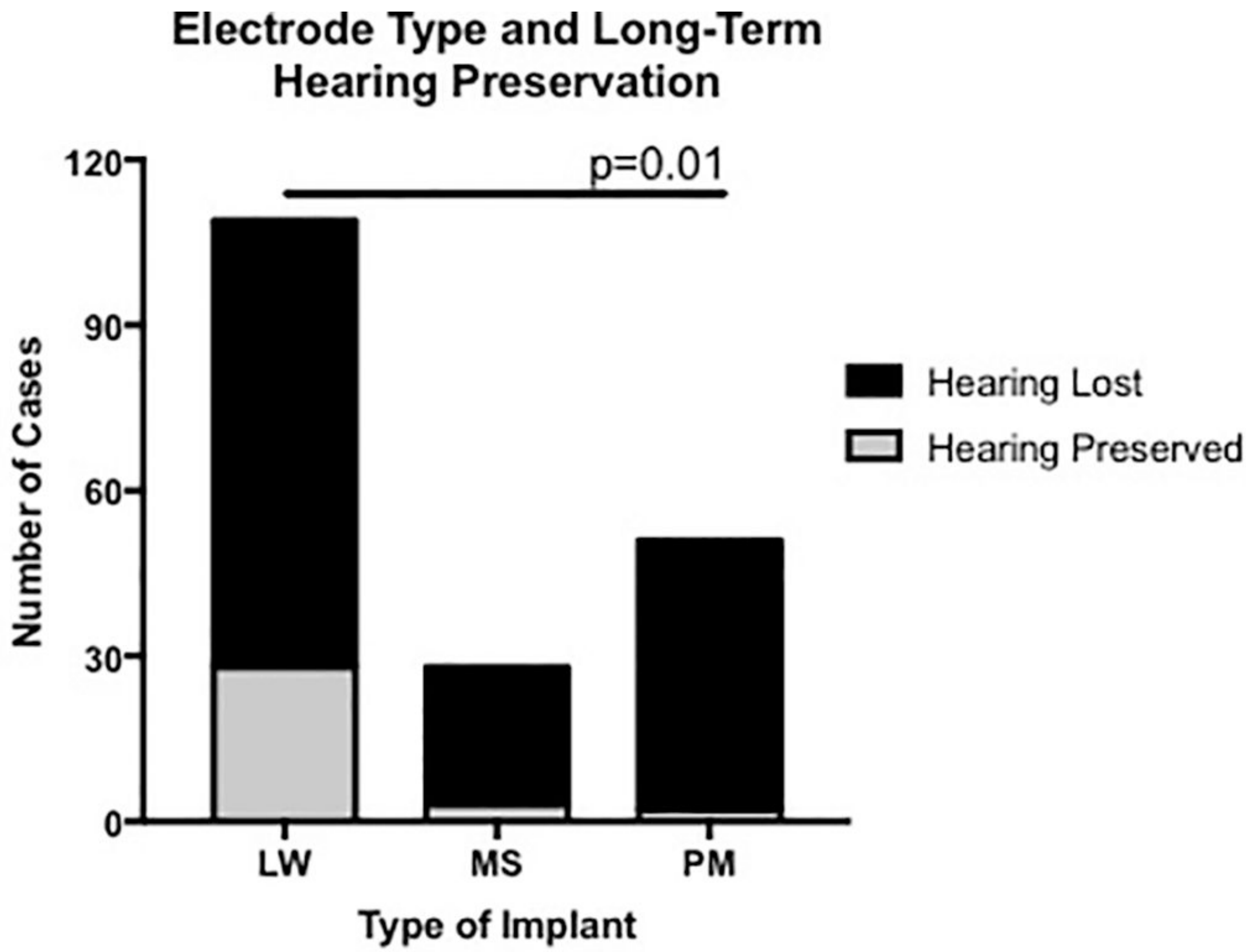

Figure 2.

Rates of long-term hearing preservation are depicted according to electrode design. LW electrodes were 8 times more likely to preserve functional hearing than perimodiolar electrodes (*p* value reflects multivariate regression statistics). LW- lateral wall, MS- mid-scala, PM- perimodiolar.

Table 1

Details regarding manufacturer and electrode arrays of included patients

	Electrode Array	n (%)
MED-EL	Flex 28	52 (23.1%)
	Flex 24	16 (7.1%)
	Standard	9 (4%)
COCHLEAR AMERICAS	Contour Advance	54 (24%)
	Slim Straight	51 (22.7%)
ADVANCED BIONICS	Mid-Scala	35 (15.6%)
	1J	7 (3.1%)
	Helix	1 (0.4%)

Table 2

Univariate analysis of covariates and short-term hearing preservation

	Preserved Hearing (≤ 80 dB HL at 250)	Loss of Residual Hearing (> 80 dB HL at 250)	p value
Age (years) (IQ range)	66.6 (55.0–74.3)	66.6 (56.6–75.9)	0.51
Pre-operative AC Threshold at 250 Hz (dB HL) (IQ range)	55.0 (40.0–60.0)	65.0 (55.0–75.0)	**<0.0001**
	n (%)	**n (%)**	
Gender			
Male	44 (52.4%)	83 (58.9%)	0.42
Female	40 (47.6%)	58 (41.1%)	
Type of Electrode			
Lateral wall	58 (69.1%)	77 (54.6%)	**0.0009**
Perimodiolar	9 (10.7%)	46 (32.6%)	
Mid-Scala	17 (20.2%)	18 (12.8%)	
Surgical Approach			
RW/ERW	77 (91.6%)	113 (80.1%)	**0.03**
Cochleostomy	7 (8.4%)	28 (19.9%)	
Post-operative Oral Steroids			
No	44 (52.4%)	91 (64.5%)	0.09
Yes	40 (47.6%)	50 (35.5%)	
Diabetes			
No	76 (90.5%)	110 (78.0%)	**0.03**
Yes	8 (9.5%)	31 (22.0%)	

(IQ: interquartile range). RW- round window, ERW- extended round window.

Table 3

Multivariate logistic regression of predictive factors for short-term hearing preservation.

Hearing Preservation Activ.	Odds Ratio	95% Confidence Interval	p value
Preop AC Threshold at 250 Hz	0.93	0.90 – 0.95	**<0.001**
Diabetes	0.51	0.18 – 1.42	0.20
Electrode Type			
Perimodiolar	Reference		
Lateral Wall	3.42	1.36 – 8.62	**0.009**
Mid Scala	5.61	1.82 – 17.34	**0.003**
Surgical Approach			
Cochleostomy	Reference		
RW/ERW	0.63	0.22 – 1.84	0.40
Post-operative Oral Steroids	1.24	0.64 – 2.40	0.52

RW- round window, ERW- extended round window.

Table 4

Univariate analysis of covariates and long-term hearing preservation.

	Preserved Hearing (≤ 80 dB HL at 250)	Loss of Residual Hearing (> 80 dB HL at 250)	p value
Age (years) (IQ range)	70.8 (53.5–76.6)	66.6 (57.0–75.8)	0.50
Pre-operative AC Threshold at 250 Hz (dB) (IQ range)	50.0 (40.0–55.0)	65.0 (55.0–75.0)	**<0.0001**
	n (%)	**n (%)**	
Gender			
Male	19 (57.6%)	89 (57.4%)	0.99
Female	14 (42.4%)	66 (42.6%)	
Type of Electrode			
Lateral wall	28 (84.9%)	81 (52.3%)	**0.002**
Perimodiolar	2 (6%)	49 (31.6%)	
Mid-Scala	3 (9.1%)	25 (16.1%)	
Surgical Approach			
RW/ERW	33 (100%)	123 (79.4%)	**0.002**
Cochleostomy	0 (0%)	32 (20.6%)	
Post-operative Oral Steroids			
No	12 (36.4%)	103 (66.5%)	**0.003**
Yes	21 (63.6%)	52 (33.5%)	
Diabetes			
No	28 (84.8%)	124 (80%)	0.63
Yes	5 (14.2%)	31 (20%)	

IQ- interquartile range, RW- round window, ERW- extended round window.

Table 5

Multivariate logistic regression of predictive factors for long-term hearing preservation.

Hearing Preservation Long-Term	Odds Ratio	95% Confidence Interval	p value
Preop AC Threshold at 250 Hz	0.94	0.91 – 0.97	**<0.001**
Diabetes	1.26	0.37 – 4.31	0.71
Electrode Type			
Perimodiolar	Reference		
Lateral Wall	7.65	1.62 – 36.14	**0.01**
Mid-Scala	3.08	0.41 – 23.12	0.28
Post-operative Oral Steroids	3.23	1.31 – 7.96	**0.01**

Table 6

Multivariate regression of predictive factors for low-frequency pure-tone average (PTA) shift.

Low-frequency PTA Shift	Coefficient	95% Confidence Interval	p value
Preop low-frequency PTA	−0.53	−0.68 – −0.39	**<0.001**
Age	0.09	−0.04 – 0.23	0.15
Diabetes	1.26	−4.14 – 6.66	0.65
Electrode Type			
Perimodiolar	Reference		
Lateral Wall	−6.99	−11.80 – −2.17	**0.005**
Mid Scala	−6.27	−12.77 – 0.21	0.06
Surgical Approach			
RW/ERW	Reference		
Cochleostomy	6.12	0.46 – 11.77	**0.03**

RW- round window, ERW- extended round window.