

Assessing the Significance of Abnormal Inserted Perimodiolar Slim Electrodes: Perception and Management Strategies

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Keywords

Cochlear implant · Electrode positioning · Speech performance · Audiologic outcomes · CT scan

Abstract

Introduction: Slim perimodiolar electrodes (PSEs) are designed for close modiolar proximity, but deviations from ideal placement may affect speech perception. This study investigates the prevalence, radiologic characteristics, and audiologic outcomes of abnormally positioned PSE arrays and proposes intraoperative management strategies. **Methods:** We retrospectively reviewed 239 adults implanted with Cochlear® PSE arrays (2015–2023). Postoperative CT scan identified arrays positioned laterally to mid-scala without tip fold-over. Objective metrics such as angular insertion depth (AID), intracochlear position index (ICPI), wrapping factor (WF), and maximum insertion angle were compared to a control group with normal positioning ($n = 52$). Speech perception outcomes at 3 and 12 months were assessed using monosyllabic word tests and compared to a reference cohort ($n = 1,414$). **Results:** Abnormal positioning occurred in 3% ($n = 7$). All arrays remained within scala tympani but had shallower in-

sertions (AID 296° vs. 392°), greater lateralization (ICPI 0.52 vs. 0.33), and higher WF (0.62 vs. 0.36). Compared to controls, speech scores were lower at 3 months (33% vs. 65%) and 12 months (45% vs. 74%). Intraoperative X-rays did not detect these deviations. **Conclusion:** Abnormal PSE placement is uncommon but associated with poorer speech outcomes. Surgeons should assess electrode shape intraoperatively and consider reinsertion if the classic curl is absent. Postoperative CT remains critical for quality assurance. Tailored intraoperative strategies are needed to prevent lateralization and optimize outcomes.

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Introduction

Cochlear implantation has emerged as the standard of treatment for individuals with moderate to profound sensorineural hearing loss (SNHL) who do not receive sufficient benefit from conventional hearing aids [1, 2]. Multiple factors have garnered attention recently due to their potential impact on speech perception and cochlear implant (CI) performance. These factors include biographical factors (age at hearing loss onset, age at implantation, duration of

hearing loss, and neurocognition), audiometric factors (preoperative residual hearing), and electrode factors (design and position) [2–4]. Notably, the influence of electrode positional factors on speech perception has gained significant interest, with studies investigating scalar location, insertion depth, and electrode to modiolus distance [1, 5].

Historically, most CI devices have used electrode arrays designed to be positioned along the scala tympani (ST) length, as this closely approximates the spiral ganglion cells. These arrays are typically inserted into the ST via the round window (RW) or an extended RW (eRW) approach [6, 7]. Adopting appropriate surgical techniques has been associated with improved speech perception outcomes and a higher likelihood of preserving residual hearing [8]. In contrast, suboptimal electrode positioning can compromise the potential efficacy of CI, as the electrode contacts may not align optimally with the target neural elements [6]. Such positioning issues may arise when the electrodes are not inserted to the intended depth, exhibit tip fold-over or deviate from ST, such as in scala vestibuli insertion or ST to scala vestibuli translocation [6].

Perimodiolar arrays, in contrast to lateral wall electrodes, are pre-curved to lie adjacent to the modiolus, enhancing neural specificity and reducing current spread [9–13]. Slim perimodiolar electrodes (PSEs) such as the Cochlear[®] CI532 and CI632 combine a reduced diameter with controlled insertion using an external sheath, to minimize trauma and reduce scalar translocation [8]. However, their increased flexibility and lack of internal stylet may also introduce a higher risk of positioning anomalies such as incomplete curling, lateralization within the ST, or insufficient apical advancement, even in the absence of scalar translocation or fold-over [8].

Postoperative CT imaging has become the gold standard for assessing electrode position, providing objective data on scalar location, angular insertion depth [AID], modiolar proximity (intracochlear position index [ICPI] or wrapping factor [WF]), and maximum insertion angle (MIA) [14, 15]. Although many studies have examined how insertion angle and scalar location affect outcomes, results remain inconsistent, particularly for perimodiolar arrays. While some studies suggest that deeper insertions may improve tonotopic alignment and speech performance, especially in lateral wall arrays [16–18], others report increased risk of trauma or lateral deviation with deeper insertions in pre-curved electrodes [5, 7, 9, 12, 19]. These discrepancies highlight the importance of electrode design when interpreting insertion metrics.

A critical gap in the literature is the limited understanding of electrode arrays that appear well-placed intraoperatively but are later found to be laterally displaced or under-inserted on postoperative imaging – particularly in the absence of classic complications such as tip fold-over or translocation. Although most studies focus on scalar location or angular depth, few have described the clinical and audiologic consequences of abnormally inserted PSE within a normal ST trajectory, and even fewer have explored how these subtle deviations correlate with functional outcomes.

This study aimed to address that gap by comprehensively describing the prevalence, imaging characteristics, and speech perception outcomes of a series of adult patients implanted with PSE arrays who exhibited abnormal positioning on postoperative CT imaging. We compare these cases to a control group with ideal PSE positioning and a large reference cohort. We aimed to identify intraoperative cues that may predict suboptimal outcomes and provide practical recommendations for intraoperative assessment and surgical decision-making.

Materials and Methods

Patients with abnormal electrode position were identified through the CI audiologic database from all postlingual adults (>18 years old) with normal cochlea implanted with a Cochlear[®] PSE ($n = 239$) between April 2015 and March 2023. A retrospective imagery (post-op cone beam CT scan) review was conducted on all patients. The same senior surgeon analyzed all scans. Initially, electrode position was identified as abnormal by subjective visualization of the electrode within the cochlea, being the entire electrode lateral to the mid-scala. This group was called “abnormal position group”. Subsequently, patients categorized as having subjective abnormal electrode position were objectively compared to a previously analyzed imagery dataset ($n = 52$) implanted with PSE in our center from 2015 to 2018 with normal cochlear anatomy and normal position of electrodes called “normal position group”. Measurement of ICPI, WF, AID, and maximum insertion angle were used and compared to document objectively abnormal position of the electrode array.

All patients included in the study had preoperative imaging (CT and MRI), intraoperative X-rays, and a cone beam CT scan postoperatively to assess electrode position. Demographic data and intraoperative implantation

Table 1. Patient characteristics and speech performance over time in the abnormal position group

Patient	Ear implanted	Age at implantation, years	Speech perception preoperative		Speech perception postoperative 3 months		Speech performance postoperative 12 months	
			words, %	phonemes, %	words, %	phonemes, %	words, %	phonemes, %
1	Right	75	18	42	30	50	26	60
2	Right	89	22	47	26	31	34	64
3	Left	82	0	0	18	46	33	58
4	Left	68	20	48	36	57	60	85
5	Left	78	0	0	12	35	14	33
6	Left	65	0	0	2	13	2	15
7	Left	46	0	0	0	0	0	0

Table 2. Comparison of patient characteristics and speech performance across the three CI insertion groups: abnormal position, normal position, and speech perception reference

Group	Patients, <i>n</i>	Average age at implantation (SD), years	Time in deafness (SD), years	Postoperative 3-month average phoneme recognition (SD), %	Postoperative 12-month average phoneme recognition (SD), %
Abnormal position group	7	72 (14)	13 (15)	33 (20.5)	44.57 (30.6)
Normal positioned group	52	66 (12)	14.8 (14.4)	65.31 (20.8)	73.5 (18.4)
Speech perception reference group	1,414	65.6 (15.6)	14.3 (13.6)	59.2 (23.8)	66.8 (22.8)

details were collected and retrospectively reviewed to determine if there were surgical difficulties in performing electrode insertion. Neural response telemetries (NRTs) were measured immediately postoperatively.

Speech perception assessment included open-set monosyllabic word testing in quiet environment, using consonant-vowel-consonant words scored based on the number of correctly identified phonemes and words. Pre-, postoperative at 3- and 12-month assessments were performed. Speech perception scores were compared to a larger cohort ($N = 1,414$) of postlingually deaf adults with bilateral hearing loss implanted with Nucleus[®] devices in Melbourne from January 2000 to June 2020 with otherwise normal cochlear anatomy. This larger cohort excluded those with documented otosclerosis as etiology, non-English speakers, and some patients with psychiatric or medical conditions precluding formal testing called "speech perception reference group". All statistical analysis was performed by using MATLAB (MathWorks[®], USA).

Results

Demographics

Seven (3%) patients out of 239 PSE implantation were included in the abnormal position group (see Table 1). The group was not significantly different for age at implantation (72 years, SD 14) than the normal position group (66 years, SD 12) and the speech perception reference group (65.6 years, SD 15.6). Regarding length in deafness in years, the abnormal inserted PSE group presented a mean of 13 years (SD 15), while the normal position group presented a mean of 14.8 years (SD 14.4) and the speech perception reference group presented a mean of 14.3 (SD 13.6) (see Table 2). Regarding the underlying cause of hearing loss all three groups exhibited bilateral SNHL. Within the abnormal position group, none of these patients had any significant residual hearing before cochlear implantation. Patients 3 and 5 had previously

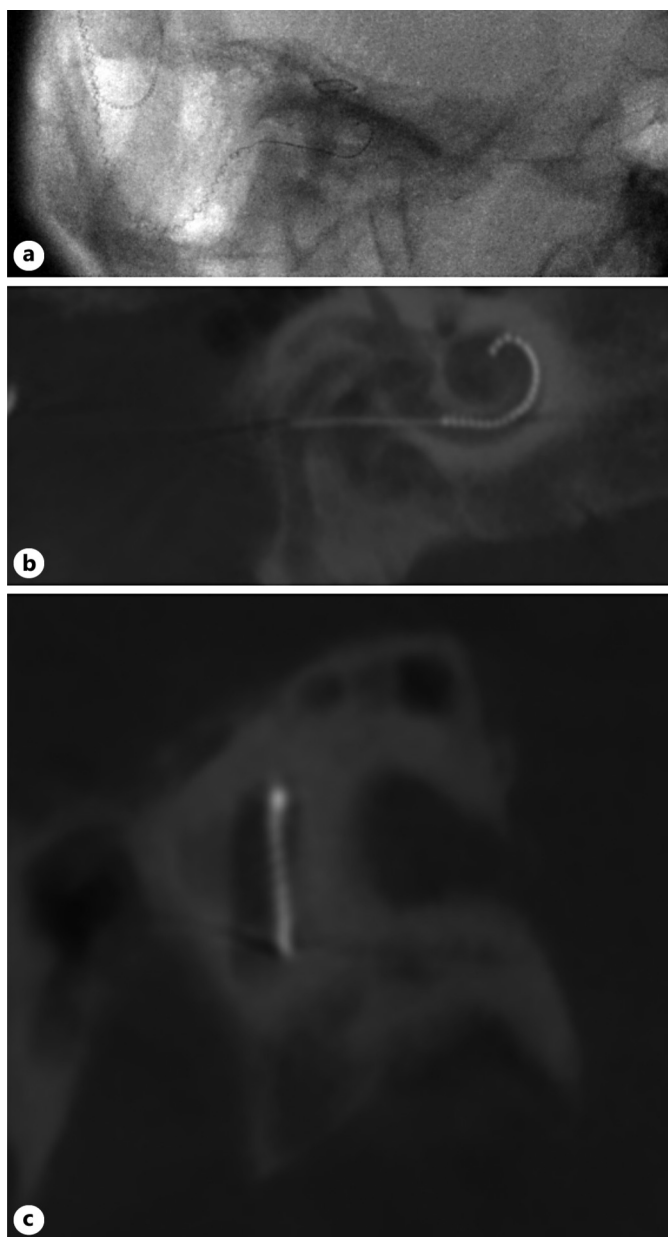


Fig. 1. **a** Intraoperative X-ray plate of patient 1. **b** Postoperative CT cone beam scan of patient 1. **c** Postoperative CT cone beam scan of patient 1 showing ST position.

undergone radiotherapy for parotid and nasopharyngeal cancer, respectively. Patient 6 experienced persistent hearing loss following Ramsay-Hunt syndrome in the left ear and subsequently developed sudden SNHL in the opposite ear. Notably, this particular patient exhibited a facial-cochlear dehiscence as revealed by her preoperative CT scan. Patient 1 reported a history of hearing loss resulting

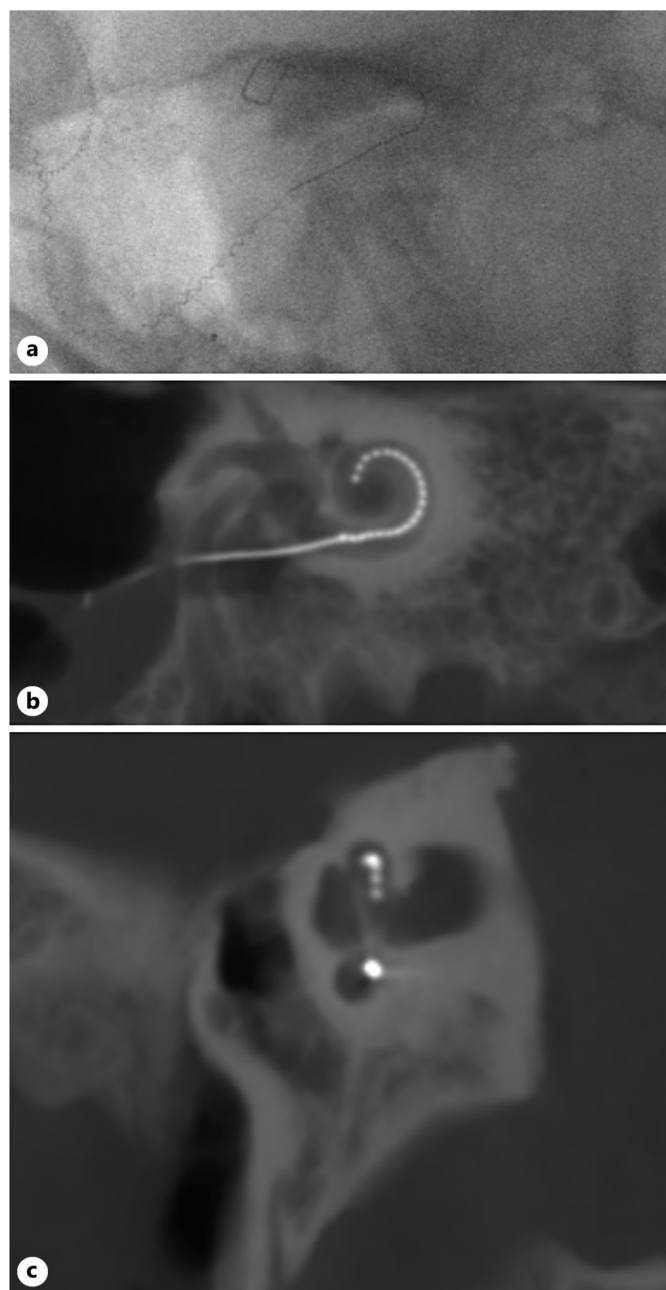


Fig. 2. **a** Intraoperative X-ray plate of patient 2. **b** Postoperative CT cone beam scan of patient 2. **c** Postoperative CT cone beam scan of patient 2 showing ST position.

from ear trauma, without any temporal bone fractures. Patient 7 presented profound congenital left ear hearing loss. Normal cochlear morphology with MRI showing a normal cochlear signal was evidenced in all patients, except for patient 6 who presented a facial-cochlear dehiscence secondary to Ramsay-Hunt syndrome.

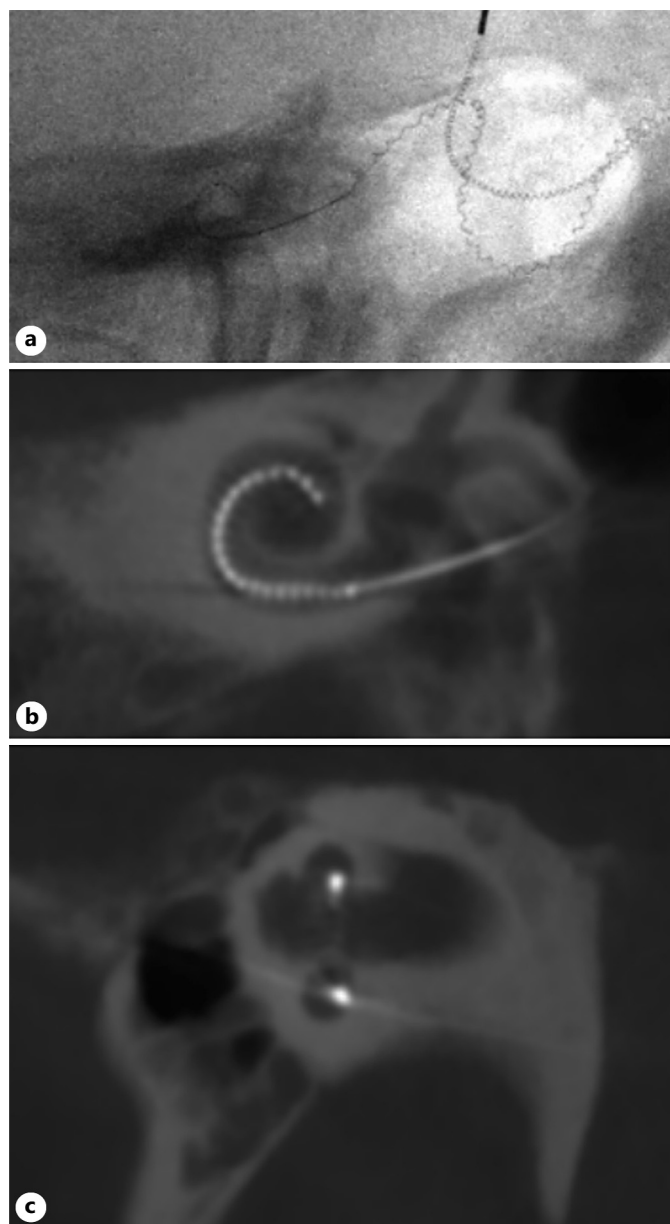


Fig. 3. **a** Intraoperative X-ray plate of patient 3. **b** Postoperative CT cone beam scan of patient 3. **c** Postoperative CT cone beam scan of patient 3 showing ST position.

Surgical Technique, Intraoperative Findings, and X-Rays Plates

All patients from both groups underwent an extended RW cochleostomy approach with unnoticeable difficulties during electrode insertion. Systematic intraoperative X-rays confirmed the absence of tip fold-over (Fig. 1a, 2a, 3a, 4a, 5a and 6a). Except for patient 4, the X-ray showed the electrode

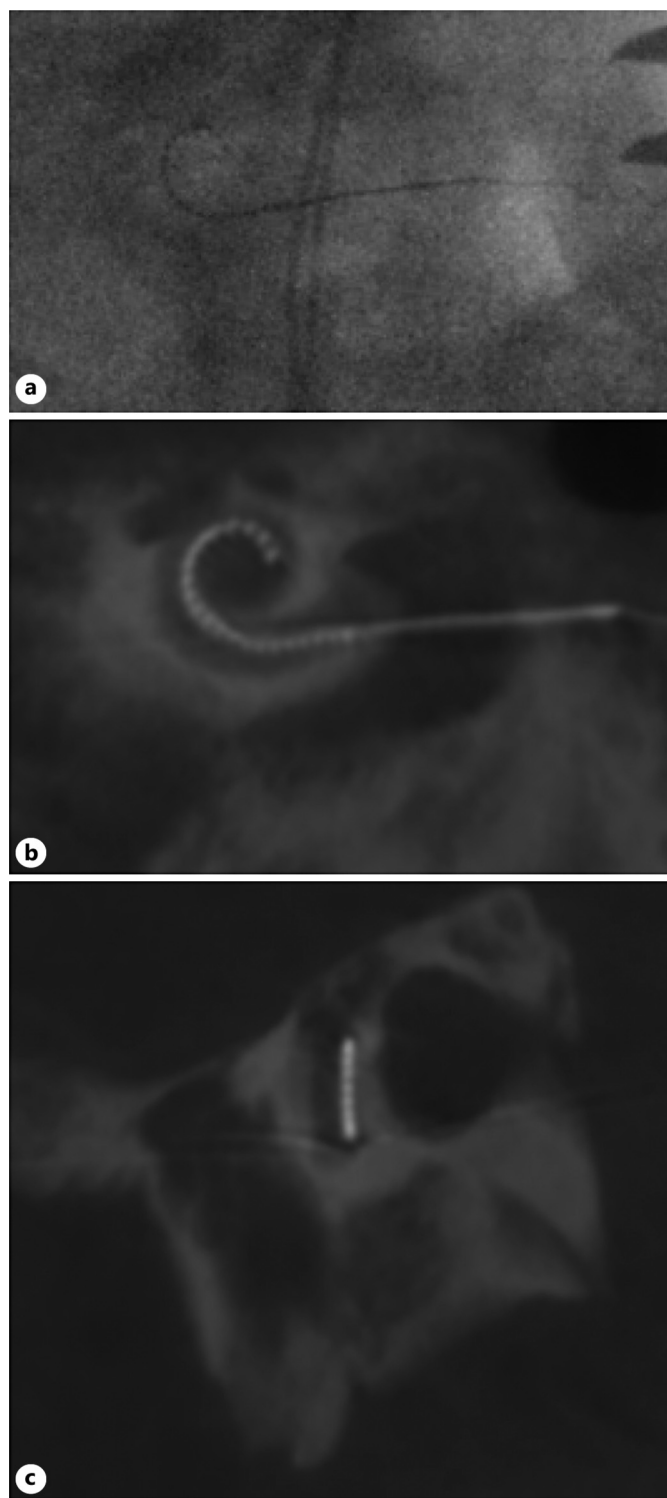


Fig. 4. **a** Intraoperative X-ray plate of patient 4. **b** Postoperative CT cone beam scan of patient 4. **c** Postoperative CT cone beam scan of patient 4 showing ST position.

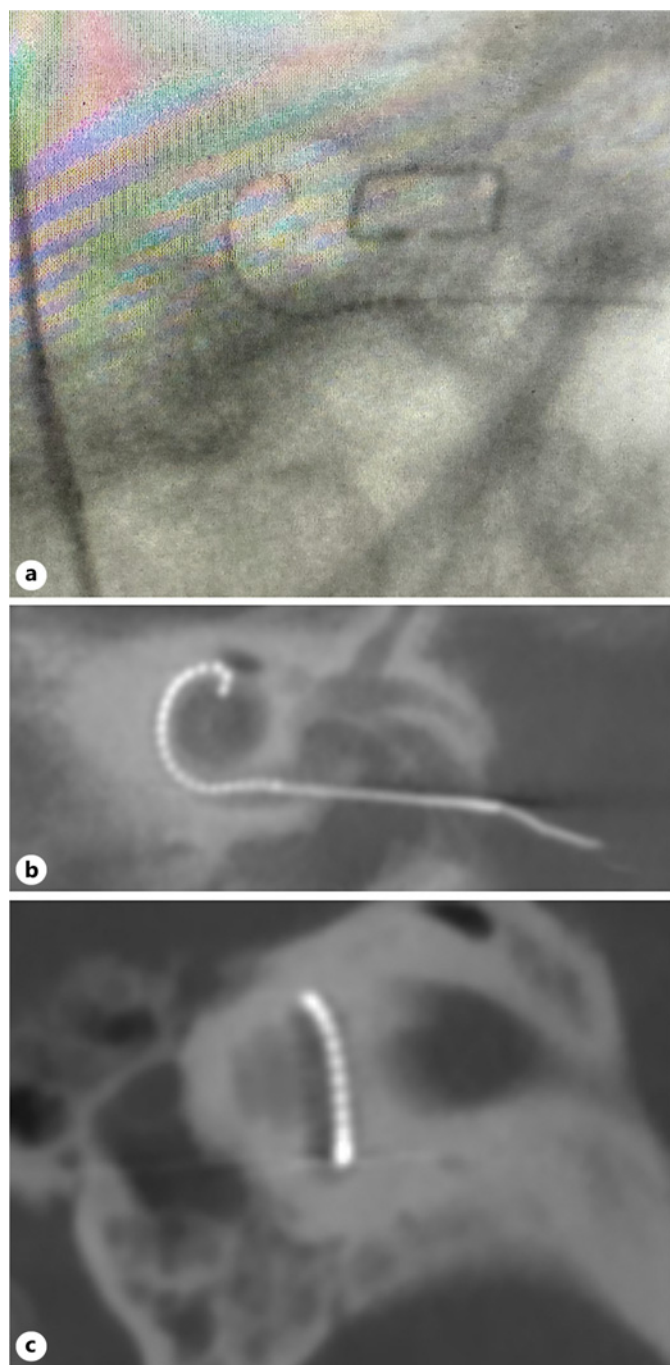


Fig. 5. **a** Intraoperative X-ray plate of patient 5. **b** Postoperative CT cone beam scan of patient 5. **c** Postoperative CT cone beam scan of patient 5 showing ST position.

position as seen in Figure 7a, described in the surgical report as “reasonably good position, although the insertion may have been less than 360°”.

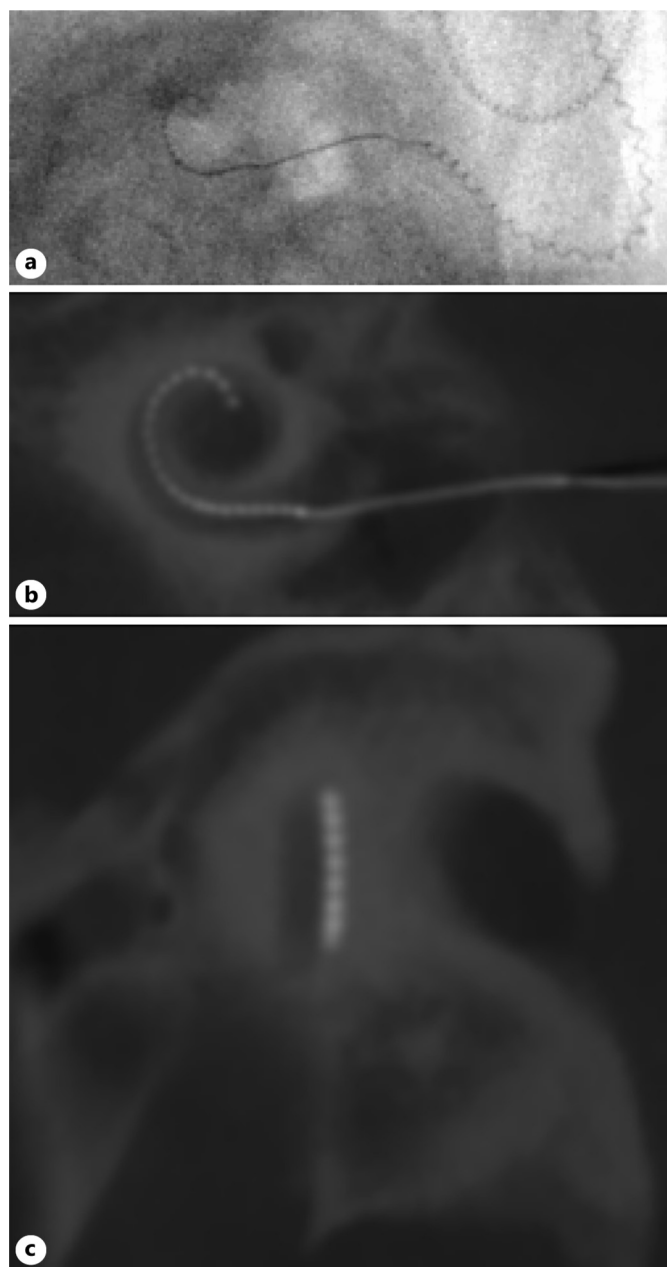


Fig. 6. **a** Intraoperative X-ray plate of patient 6. **b** Postoperative CT cone beam scan of patient 6. **c** Postoperative CT cone beam scan of patient 6 showing ST position.

Intraoperative Neural Response Telemetry

NRTs in the abnormal position inserted PSE were slightly higher compared to the normal insertion group, with a mean of 188 μ V (SD 22 μ V). Whereas the ideally inserted PSE group mean NRTs were 181 μ V (SD 22 μ V) (see Fig. 8).

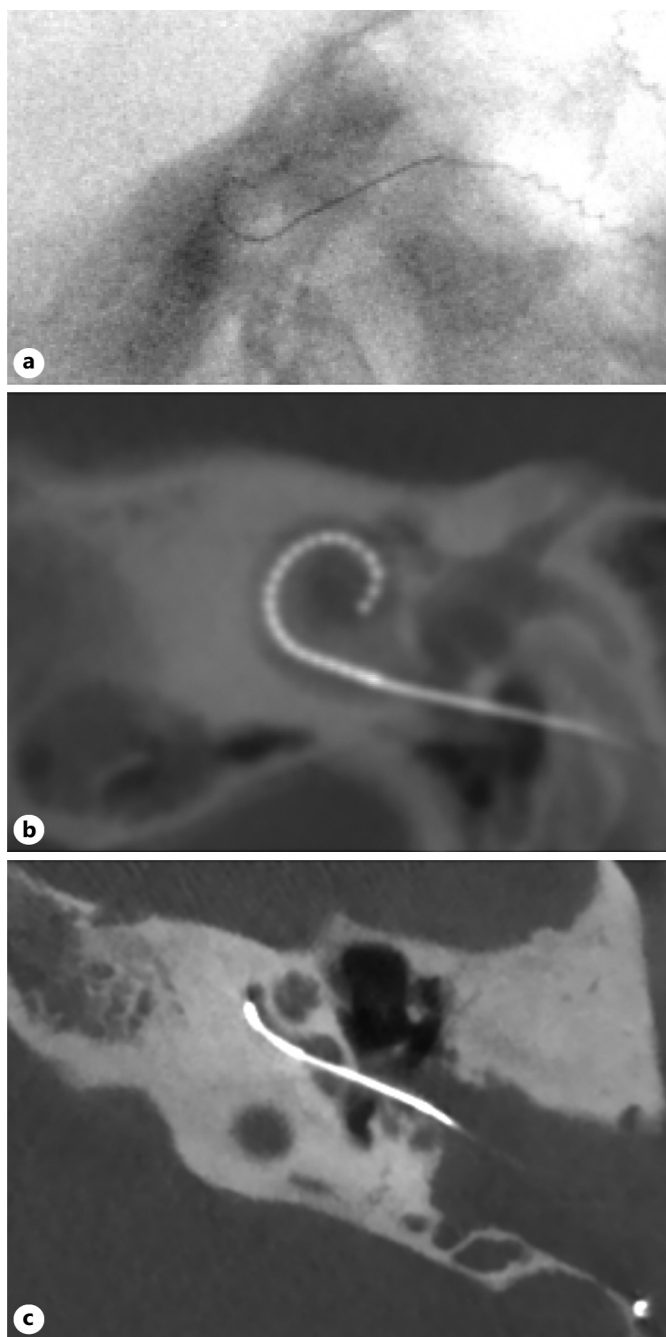


Fig. 7. **a** Intraoperative X-ray plate of patient 7. **b** Postoperative CT cone beam scan of patient 7. **c** Postoperative CT cone beam scan of patient 7 showing ST position.

Postoperative CT Scan Electrode Position and Metrics

The average insertion angles were 296° (SD of 37°) for the group with abnormal positioning, and 392° (SD of 28°) for the group with normal positioning (Fig. 9). When looking at the electrodes in the apical region (15–22), the abnormal

positioning group showed less favorable AID than the normal group (Fig. 10). Similarly, the abnormal group exhibited higher values for the lateral wall proximity measured by the WF (Fig. 11) and the ICPI (Fig. 12). These higher values indicate that the electrodes were positioned closer to the lateral wall and had a shallower insertion angle.

This observation is supported by the measurement of the maximum insertion angle, which was found to be lower in the abnormal group (114°). Notably, the most deeply inserted electrode among the group with abnormally positioned electrodes reached an insertion angle of 340° . Regarding ICPI values, the abnormal group had a higher average of 0.52, whereas the normal group's average was 0.33. Similarly, when comparing the WF values, the abnormal group showed a higher average of 0.62, contrasting with the ideally positioned group of electrodes with an average of 0.36. In both groups, all patients showed ST insertions.

Correlation between Hearing Outcomes and Electrode Position

Three months after implantation, the group with abnormal insertions ($n = 7$) exhibited an average phoneme recognition score of 33% (SD 20.5%) on the CI side, significantly lower than the well-positioned group ($n = 52$), which achieved 65.3% (SD 20.8%) ($p = 0.013$) (Fig. 13), and the larger reference cohort ($n = 1,414$), which scored 59.2% (SD 23.8%). At 12 months, the abnormal group showed some improvement (mean 44.6%, SD 30.6%), but performance remained lower than both the normal positioning group (73.5%, SD 18.4%) (Fig. 13) and the reference group (66.8%, SD 22.8%). The difference at 12 months between the abnormal and well-positioned groups approached statistical significance ($p = 0.057$).

Although the correlation was not statistically significant, ICPI showed a moderate negative association with consonant-vowel-consonant phoneme scores in the abnormal positioning group at both 3 months ($r = -0.56$, $p = 0.25$) and 12 months ($r = -0.61$, $p = 0.20$). This trend suggests that greater lateralization of the electrode array may impair speech outcomes in suboptimally positioned cases. In contrast, no significant relationship was observed in the well-positioned group (SP3: $r = 0.08$, $p = 0.88$; SP12: $r = 0.54$, $p = 0.27$), consistent with the expectation that when electrodes lie near the modiolus, minor variation in proximity may not substantially influence performance. While underpowered for significance, these findings support modiolar proximity's clinical relevance, particularly when electrode positioning is suboptimal.

This interpretation is supported by the group-wise comparisons shown in Figure 14, where patients with poorly

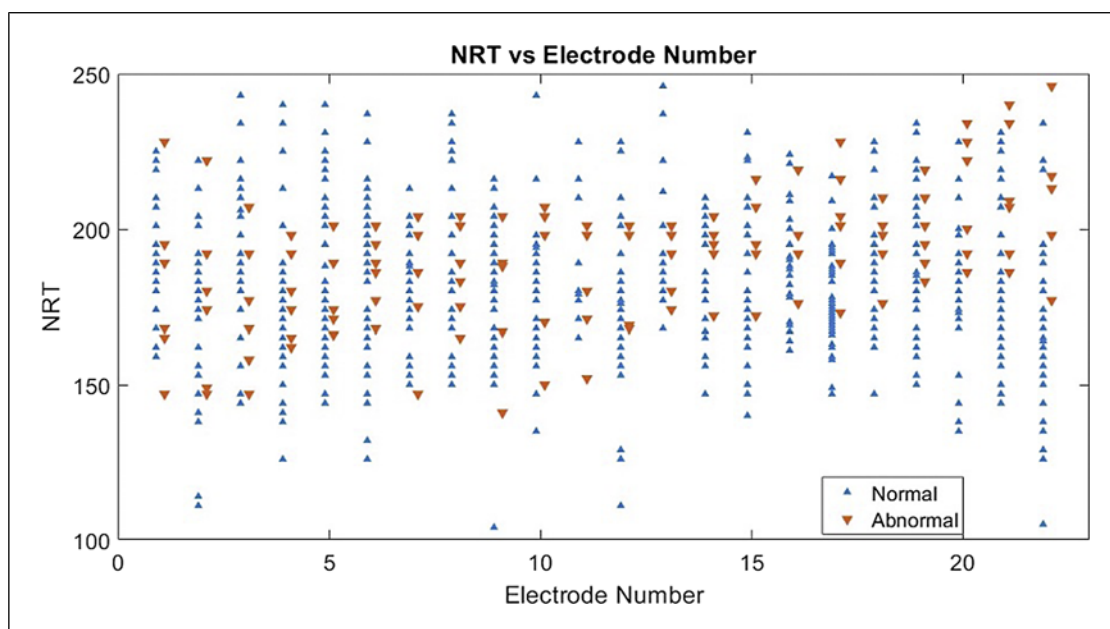


Fig. 8. Comparison of neural telemetry responses in normal versus abnormal position groups.

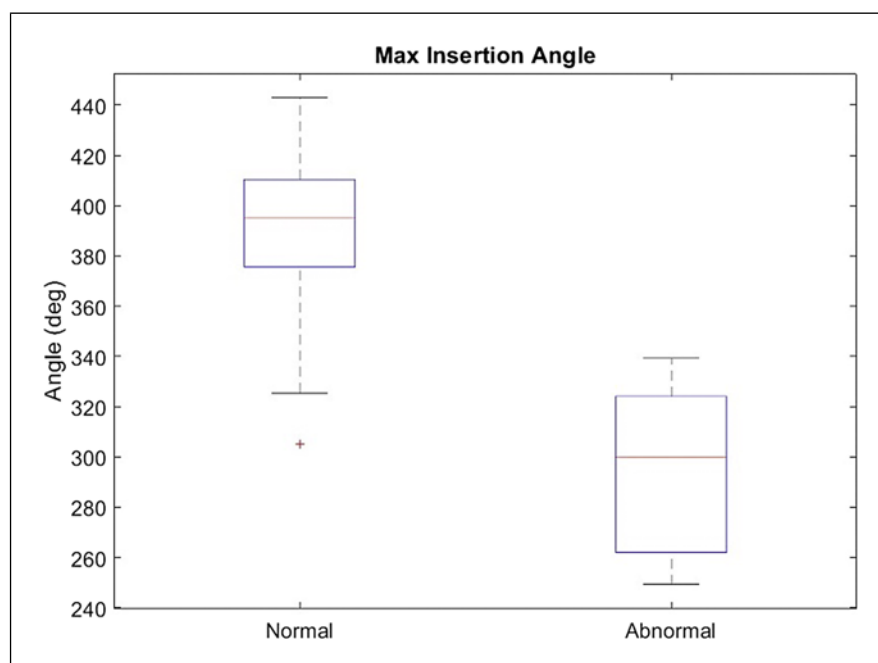


Fig. 9. Comparison of maximum insertion angle in normal versus abnormal position groups.

positioned electrodes exhibited significantly lower speech scores at 3 months ($p = 0.017$). However, this difference was no longer evident at 12 months ($p = 0.387$). These findings reinforce the clinical relevance of modiolar proximity, particularly in early postimplantation outcomes among sub-optimally inserted arrays.

Discussion

Electrode Positioning and Speech Outcomes

Speech perception outcomes following cochlear implantation remain highly variable, influenced by surgical, audiological, and patient-related factors [1]. Among these,

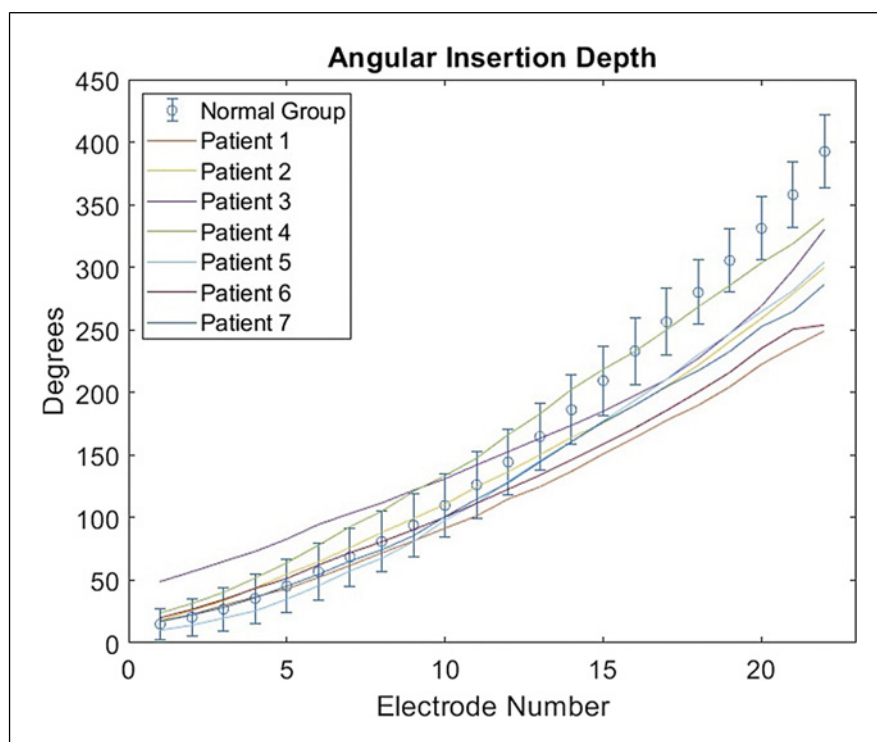


Fig. 10. Comparison of angular insertion depth in normal versus abnormal position groups.

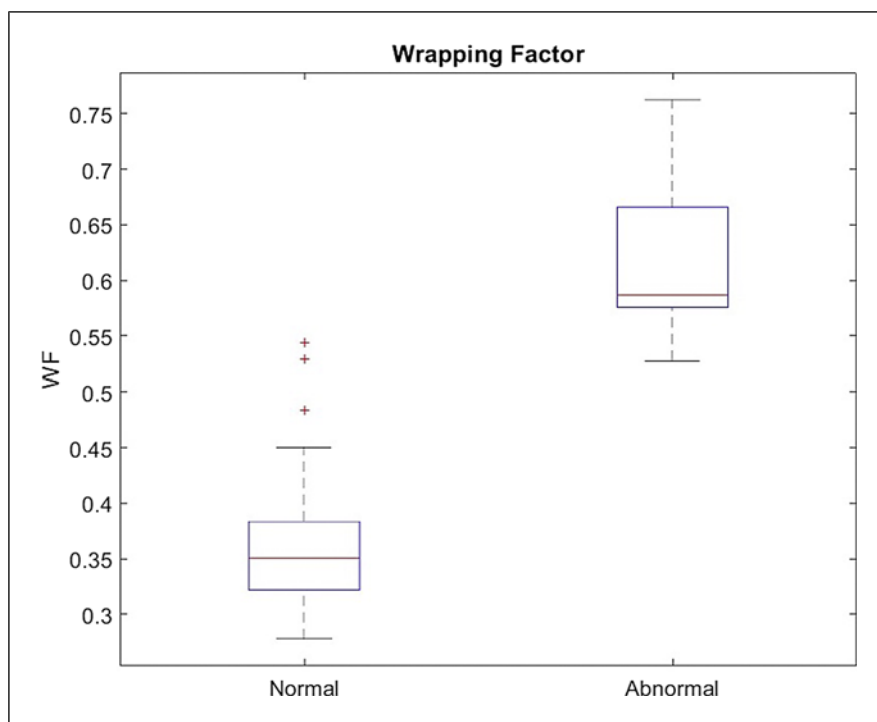


Fig. 11. Comparison of wrapping factor in normal versus abnormal position groups.

increasing attention has been directed toward the positioning of the electrode array within the cochlea – specifically, scalar location, insertion depth, and modiolar proximity – as these factors significantly influence the efficiency of neural stim-

ulation and subsequent hearing performance [6, 9, 11, 12, 19]. While correct placement facilitates focused stimulation and reduced current spread, suboptimal positioning, even within the ST, may hinder device performance [6, 9, 11, 12, 19].

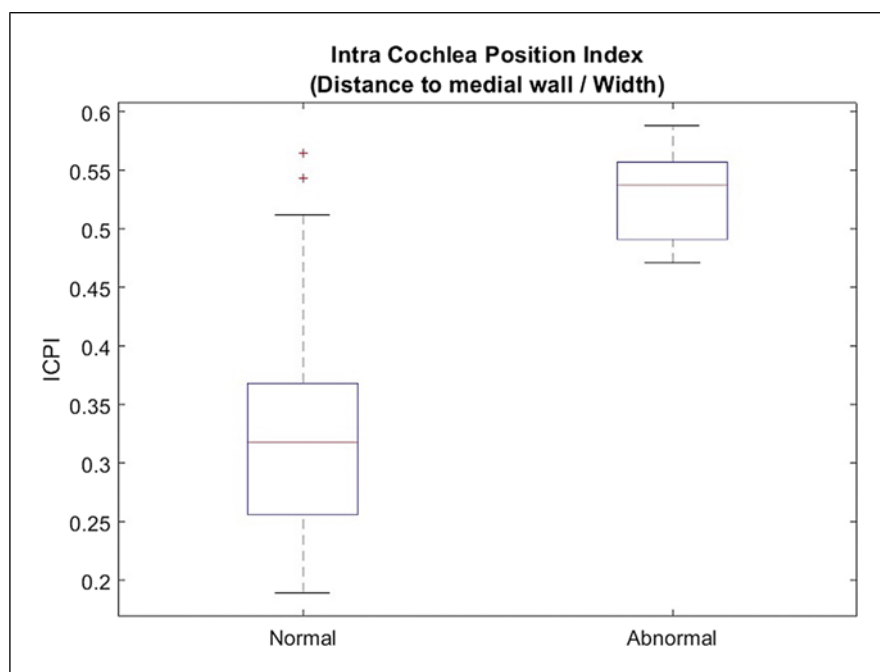


Fig. 12. Comparison of intracochlear position index (ICPI) in normal versus abnormal position groups.

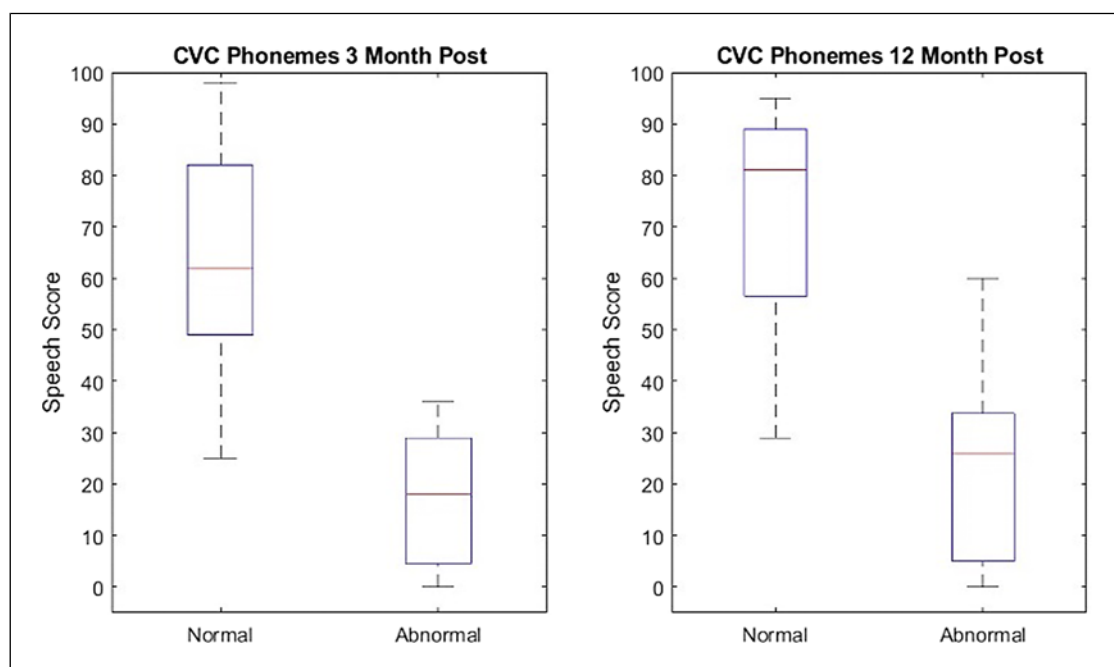


Fig. 13. Comparison of speech outcomes at 3- and 12-month postoperative: normal versus abnormal position groups.

Intraoperative Imaging: Strengths and Limitations

Intraoperative X-rays remain widely used to confirm electrode integrity and ensure that the array reaches the cochlear apex. Their accessibility and

immediacy offer real-time feedback to surgeons, enabling reinsertion if tip fold-over or gross mispositioning is suspected [20]. However, their accuracy in assessing finer details – such as curling patterns or

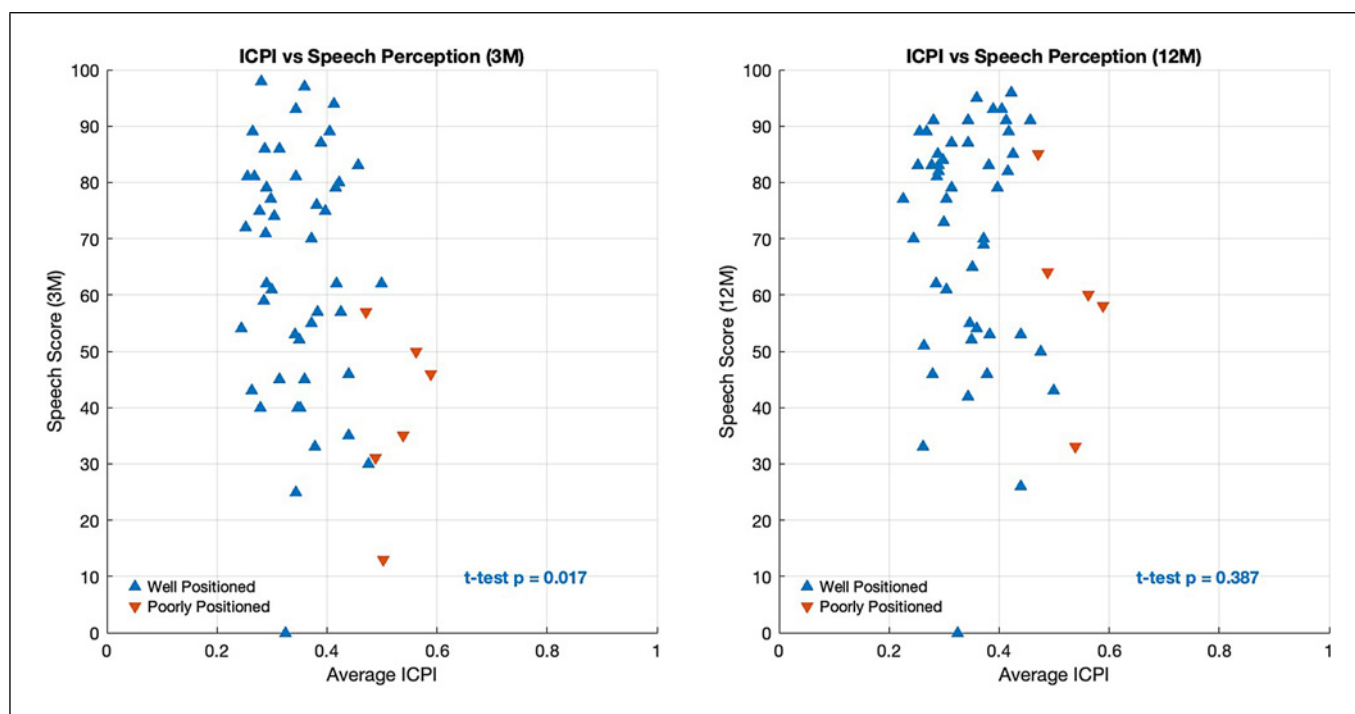


Fig. 14. Association between modiolar proximity (ICPI) and speech perception scores at 3 and 12 months.

modiolar proximity – remains limited [21]. Electrophysiological tests may supplement this assessment but cannot reliably detect lateralization or premature curling [22]. Postoperative cone beam CT has therefore emerged as the gold standard for detailed analysis of array trajectory, scalar location, and angular metrics, offering essential insights that may not be captured intraoperatively [4, 14].

Findings from Our Cohort

In this study, we identified seven adult CI recipients (3%) with abnormal positioning of SPE based on postoperative CT imaging. All arrays were confirmed to reside within the ST, with no evidence of translocation or tip fold-over, and no cochlear malformations were present. However, all cases showed a combination of shallower insertion depths and increased lateralization, and speech outcomes were consistently lower than those observed in control patients and the broader reference cohort.

Despite surgeons reporting satisfactory X-ray findings in six of the seven cases, retrospective analysis revealed characteristic deviations: incomplete or flattened curl, and a trajectory deviating from the modiolus (Fig. 1–7). The mean AID in the abnormal group was 296°, notably lower than the 392° observed

in the control group, despite full advancement to the white marker in all cases. These findings suggest that intraoperative assessment based solely on marker position may provide a false sense of security and that the curling pattern offers more valuable positional feedback.

Deep versus Shallow Insertion in Perimodiolar Arrays

The clinical relevance of insertion depth is nuanced and must be interpreted in the context of array design. In lateral wall electrodes, deeper insertions often lead to improved cochlear coverage and better alignment with the tonotopic map, thereby enhancing outcomes [16–18]. However, this benefit does not necessarily extend to perimodiolar arrays. These electrodes are pre-curved to lie adjacent to the modiolus, and their intended target, the spiral ganglion, is most densely concentrated within the basal 450° of the cochlear turn [23, 24]. Shallower insertions in this context may be not only adequate but ideal, as they preserve proximity to the neural target while minimizing the risk of trauma. Over-insertion of perimodiolar arrays may lead to deviation from the modiolus, increased wrapping factor or ICPI, and potential displacement toward the lateral wall [11, 12, 19]. Conversely, under-insertion can lead to sub-optimal stimulation of apical regions and poor

frequency-place matching, which is associated with degraded speech understanding [5, 25, 26]. In our series, both phenomena were observed: shallow AIDs and lateral displacement, negatively affecting performance.

Mechanisms behind Abnormal Positioning

The underlying mechanisms for these positioning anomalies remain speculative. All 7 patients had normal cochlear anatomy, and none showed preoperative evidence of ossification or fibrosis, except for patient 6 who presented with a cochlear facial dehiscence. Surgeons did not report insertion resistance in most cases, yet, postoperative CT revealed shallower insertions, increased lateralization, and poor modiolar proximity.

One plausible explanation involves minor intraluminal obstruction – such as blood, bone dust, or microscopic fibrous tissue – that may have subtly redirected the electrode path [6]. Although not visible on imaging, such resistance could prevent the array from achieving the characteristic curl or perimodiolar trajectory, especially in slim designs dependent on passive deployment via an external sheath [6]. This is supported by findings in patient 6, where CT imaging suggested electrode resistance and a slight indication of tip fold-over near the facial-cochlear dehiscence.

Another contributing factor may be cochlear morphological variability [27]. Studies have demonstrated that cochlear size, duct length, and modiolus diameter can influence how a given electrode conforms to the intracochlear space [27, 28]. Larger cochleae may produce shallower AIDs for the same electrode length [9, 27, 29]. Additionally, deeper insertions encounter tighter turns and a narrowing lumen toward the apex, which may predispose pre-curved electrodes to displacement or tip fold-over [28]. Fixed-sheath insertion tools may further limit the electrode's ability to adapt to such anatomical variation, increasing the risk of lateralization in cases of abnormal curvature or resistance.

Importantly, while all intraoperative X-rays in our series were initially deemed satisfactory – except for patient 4 – retrospective analysis revealed consistent signs of suboptimal positioning. In nearly all cases, the electrode tip lacked full curvature, and the array body appeared marginally displaced from the modiolus. These subtle deviations were only appreciated when comparing intraoperative radiographs with postoperative CT scans, emphasizing the need for heightened intraoperative vigilance and critical image review (Fig. 1–7).

In summary, even without cochlear anomalies, patient-specific anatomy and minor mechanical dis-

ruptions may contribute to non-perimodiolar positioning. These findings highlight the importance of preoperative assessment of cochlear dimensions and a low threshold for intraoperative reinsertion when the characteristic electrode curl is absent.

Clinical Implications and Intraoperative Recommendations

Given our series' clear association between abnormal positioning and reduced speech perception, we emphasize the importance of scrutinizing intraoperative images for deviations from the expected curling pattern. A flattened or incomplete curl should raise immediate suspicion for lateralization. In such cases, the surgeon may consider a gentle withdrawal and re-advancement of the array, if no position improvement, a complete reinsertion should be attempted. If this is also unsuccessful, replacement with a stiffer perimodiolar design such as the Contour Advance cannot be achieved if satisfactory positioning is not achieved.

We recommend that final X-rays not only confirm full insertion and display the PSE array's characteristic modiolus-hugging trajectory. If this morphology is absent, further imaging or revision should be considered.

Limitations and Directions for Future Research

This study is limited by its retrospective design, small sample size, and the absence of a perfectly matched control group exhibiting poor speech outcomes despite ideal electrode placement. Although the consistent radiologic findings and speech perception patterns in the abnormal group support the hypothesis that electrode positioning played a central role, we cannot exclude the influence of other factors. Patient-specific variables such as age, neurocognition, cochlear health, and underlying etiology may also have contributed to reduced performance, and these factors were not fully controlled in our analysis.

Several reports in the literature focus on the need for CI revision surgery, but recommendations are generally limited to more severe cases, such as tip fold-over [8, 27]. In those cases, reimplantation is strongly advocated when detected intraoperatively or postoperatively. However, applying this paradigm to patients with lateralized or shallowly inserted electrodes, particularly when there is no translocation or fold-over, is more complex. Whether revision surgery would lead to measurable improvements in speech outcomes remains unclear.

Our findings raise the question of whether patients with abnormal electrode positioning, but stable scalar

location should be considered for early revision or instead managed conservatively with close follow-up and potential reprogramming. There is insufficient evidence to support reimplantation in these cases, and clinical decision-making remains challenging.

These challenges emphasize the limitations of retrospective single-center studies and highlight the need for well-designed prospective research. Future investigations should systematically evaluate intraoperative imaging, surgical technique, and post-op radiology in real time. Multicentre cohorts are needed to identify predictive anatomical or procedural risk factors that predispose to lateralization, such as cochlear duct length, insertion angle, or sheath handling. Longer-term follow-up is also essential to determine whether initial suboptimal positioning continues to affect performance over time and to clarify whether reimplantation or reprogramming offers a tangible benefit.

Conclusion

Abnormal positioning of PSE remains an uncommon complication, occurring in only 3% of cases in this cohort. However, its impact on auditory outcomes is clinically meaningful and likely under-recognized. The experience and expertise of our surgical team, combined with the fact that our center is a high-volume referral institution, may explain the low incidence observed. Nonetheless, these findings highlight the importance of appropriate device familiarity, continuous surgical training, and careful intraoperative assessment.

As perimodiolar arrays continue to evolve and become more widely used, understanding their behavior during insertion, and interpreting subtle intraoperative cues, will be key to minimizing complications. This study provides early evidence that features such as a flattened curl, shallow insertion angle, and increased lateralization (as quantified by ICPI and WF) may serve as early red flags for suboptimal outcomes. Incorporating these indicators into routine surgical workflows may help

identify at risk patients, inform intraoperative decision-making, and potentially improve long-term speech perception outcomes.

Statement of Ethics

This study protocol was reviewed and approved by the Royal Victorian Eye and Ear Hospital Human Research Ethics Committee (HREC), Approval No. 19/1428HL. As this was a retrospective study, the requirement for written informed consent was waived by the HREC.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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The present study did not require funding.

Author Contributions

P.H.R. conceptualized the study, collected the data, and was the lead author in drafting and revising the manuscript. A.C. performed the statistical analysis, contributed to data interpretation, and assisted in manuscript preparation. J.-M.G. and G.G. provided supervision throughout the project, critically revised the manuscript, and contributed to the interpretation of the findings. All authors meet the ICMJE criteria for authorship and approved the final version of the manuscript.

Data Availability Statement

The datasets generated and/or analyzed during the current study are not publicly available due to patient privacy and institutional restrictions. However, de-identified data may be available from the corresponding author upon reasonable request and with permission from the Royal Victorian Eye and Ear Hospital Human Research Ethics Committee.

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