Journal of Otology 18 (2023) 208–213

Contents lists available at ScienceDirect

Journal of Otology

journal homepage: www.journals.elsevier.com/journal-of-otology/

# Comparing accuracy of cochlear measurements on magnetic resonance imaging and computed tomography: A step towards radiation-free cochlear implantation

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ARTICLE INFO

*Article history:*
Received 31 July 2023
Received in revised form
20 August 2023
Accepted 21 August 2023

*Keywords:*
Cochlear implant
Hearing loss
Cochlea anatomy
Radiology

ABSTRACT

*Objective:* Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are commonly employed in pre-operative evaluation for cochlear implant surgery. However, with a decrease in the age of implantation, even minor radiation exposure can cause detrimental effects on children over their lifetime. The current study compares different cochlear measurements from CT and MRI scans and evaluates the feasibility of using only an MRI scan for radiological evaluation before cochlear implantation.
*Methods:* A longitudinal observational study was conducted on 94 ears/47 children, employing CT and MRI scans. The CT and MRI scan measurements include, A value, B value, Cochlear duct length (CDL), two-turn cochlear length, alpha and beta angles to look for cochlear orientation. Cochlear nerve diameter was measured using MRI. The values were compared.
*Results:* The mean difference between measurements from CT and MRI scans for A value, B value, CDL, and two-turn cochlear length values was 0.567 ± 0.413 mm, 0.406 ± 0.368 mm, 2.365 ± 1.675 mm, and 2.063 ± 1.477 mm respectively without any significant difference. The alpha and beta angle measures were comparable, with no statistically significant difference.
*Conclusion:* The study suggests that MRI scans can be the only radiological investigation needed with no radiation risk and reduces the cost of cochlear implant program in the paediatric population. There is no significant difference between the measurements obtained from CT and MRI scans. However, observed discrepancies in cochlear measurements across different populations require regionally or race-specific standardized values to ensure accurate diagnosis and precision in cochlear implant surgery. This aspect must be addressed to ensure positive outcomes for patients.


## 1. Introduction

High-resolution computed tomography (HRCT) and magnetic resonance imaging (MRI) of the brain and temporal bone form the pillars of radiological evaluation for cochlear implant surgery. These investigations are conducted solely in the patient's best interest (Yigit et al., 2019).

The primary benefit of MRI is improved soft tissue resolution, enabling the early detection of ossification and the evaluation of the cochlear nerve. However, the time required for an MRI is long, and most patients require sedation, especially in the paediatric population (Yigit et al., 2019).

The main advantages of HRCT include better visualization of the bony labyrinth anomalies, enlarged vestibular aqueduct, the dimension of the internal auditory canal, and anatomical variations

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Peer review under responsibility of PLA General Hospital Department of Otolaryngology Head and Neck Surgery.

https://doi.org/10.1016/j.joto.2023.08.001

(Yigit et al., 2019). Moreover, prolonged sedation is unnecessary for most children who undergo CT scans.

Despite the decline in radiation levels from CT scans, the decreasing age of implantation still exposes young children to radiation. The potential for severe impact persists due to cumulative exposure over a long period, as even children as young as one year old undergo implantation. The cumulative doses of radiation exceeding 50 mGy could potentially triple the risk of leukaemia and brain tumours in children (Pearce et al., 2012).

Moreover, advancements in implant structure have rendered the insertion atraumatic and more effortless, thus shifting the trend towards a minimally invasive approach.

We propose that an MRI scan can provide all the necessary data for implantation with the expertise of an experienced team. A CT scan can be reserved for patients with severe malformations. This aims to minimize radiation exposure and program costs. The study compares CT and MRI scan measurements for the right and left sides, male and female, and between CT and MRI.

## 2. Objectives

a) To evaluate the accuracy of an MRI scan to measure “A" and “B" values compared to HRCT temporal bone.
b) To compare the measurements of cochlear duct length and two-turn cochlear length, alpha and beta angle values acquired from CT and MRI scans and their relation with the implant insertion.

## 3. Materials and methods

A longitudinal observational study comprising 47 children, i.e., 94 ears, were enrolled from July 2020 to June 2022. All children diagnosed with severe to profound hearing loss who underwent cochlear implantation and met inclusion and exclusion criteria were enrolled in the study. Children with cochlear deformities seen in CT or MRI and with comorbidities were excluded. All patients underwent HRCT temporal bone and MRI of the inner ear and brain. All children were sedated in the presence of a paediatrician before undergoing an MRI scan. Ethical clearance was obtained from Institutional Ethics Committee, AIIMS Bhubaneswar, Referral number: IEC/AIIMS BBSR/PG Thesis/2020-21/57.

All MRI scans were conducted using a 1.5 T MRI scanner (Siemens Magnetom area) encompassing routine imaging such as T2 weighted imaging (T2WI), T1 weighted imaging (T1WI), fluid-attenuated inversion recovery (FLAIR), diffusion-weighted imaging (DWI), susceptibility-weighted imaging, and magnetization-Prepared Rapid Acquisition Gradient Echo (MP-RAGE) of the brain aiming to exclude neuro-parenchymal abnormalities. The T2-SPACE sequence was acquired, targeting the internal auditory canal (IAC) and inner ear to assess the cochlea, 7th, and 8th nerve complex. Cochlear nerve diameter was obtained from the oblique sagittal reformatted image on heavilyT2WI.

Alpha and Beta angle measurements were taken from acquired T2WI in MRI. The cochlea was evaluated for its cochlear turns and potential deformity using the 3D T2 SPACE sequence. The A and B values were derived from the 3D reconstruction of the cochlea in the 3D T2-SPACE sequence.

All patients underwent HRCT of the temporal bone in a 256-slice CT scanner (SIEMENS, Somatom Definition Flash Model). The alpha angle and beta angle measurements were acquired from axial images of HRCT temporal bone scans. The A value and B values were obtained from oblique coronal reformatted images.

Post-processing was conducted using a Syngovia system, and a radiologist took measurements. Statistical Package for Social Sciences (SPSS) version 25 was performed using statistical analysis. An independent sample *t*-test was used to compare the distinct variables.

**Measurements using CT scan and MRI scan** (Figs. 1 and 2):

- “A" value
- “B" value
- Alpha angles.
- Beta angle

**Measurement using MRI scan** (Fig. 3):

- Cochlear nerve diameter

***“A" value*** was measured as the largest distance from the center of the round window to the lateral wall of the cochlea passing through the modiolus in the oblique sagittal reconstruction of the cochlea.

“***B" value*** was measured by drawing a line perpendicular to the “A" value passing through the modiolus in the oblique sagittal reconstruction of the cochlea.

***Alpha angle*** was measured by calculating the angle between the mid-sagittal plane and the long axis of the basal turn of the cochlea in the axial section.

***Beta angle*** was measured by calculating the angle between the long axis of the cochlea and the surgical axis (the line passing along the posterior wall of the external auditory canal) on the axial section.

The maximum ***diameter of the cochlear nerve*** was measured using an oblique sagittal reformatted image on heavily T2WI.

### 3.1. Measurement of cochlear duct length and two-turn cochlear length

The cochlear duct length and two-turn cochlear length were measured manually using the following equations by Alexiades et al. (2015):

$$CDL(OC) = 4.16(A) - 4$$

$$2\ TL(OC) = 3.65\ x(A\text{-}1)$$

Here, “A” represents the diameter of the basal turn of the cochlea measured on a CT scan.

## 4. Results

Among 47 children, 25(53%) were male, and 22(47%) were female, with an age group ranging from 1 to 12 years. There was no statistically significant difference between the genders. Children with deformed cochlea and with comorbidities were excluded.

### 4.1. Comparison of values measured in CT and MRI scans

The A value, B value, CDL, 2 T CDL, alpha angle and beta angle, and cochlear nerve diameter were compared between the right and left sides in CT and MRI scans (Table 1).

All left and right ear values were calculated and compared separately in CT and MRI scans; no statistical difference was noted.

In CT scans, the mean A value measured 8.191 mm on the right side and 8.415 on the left side, yielding a P-value of 0.317. The mean B value on the right side was 6.313 mm and 6.270 mm on the left side, with a P-value of 0.741. Similarly, comparing the cochlear duct length between the right (29.208 mm) and left (29.744 mm) ear obtained a P-value of 0.342. For two-turn Cochlear length mean value on the right side was 25.483 mm, 26.149 on the left side, and

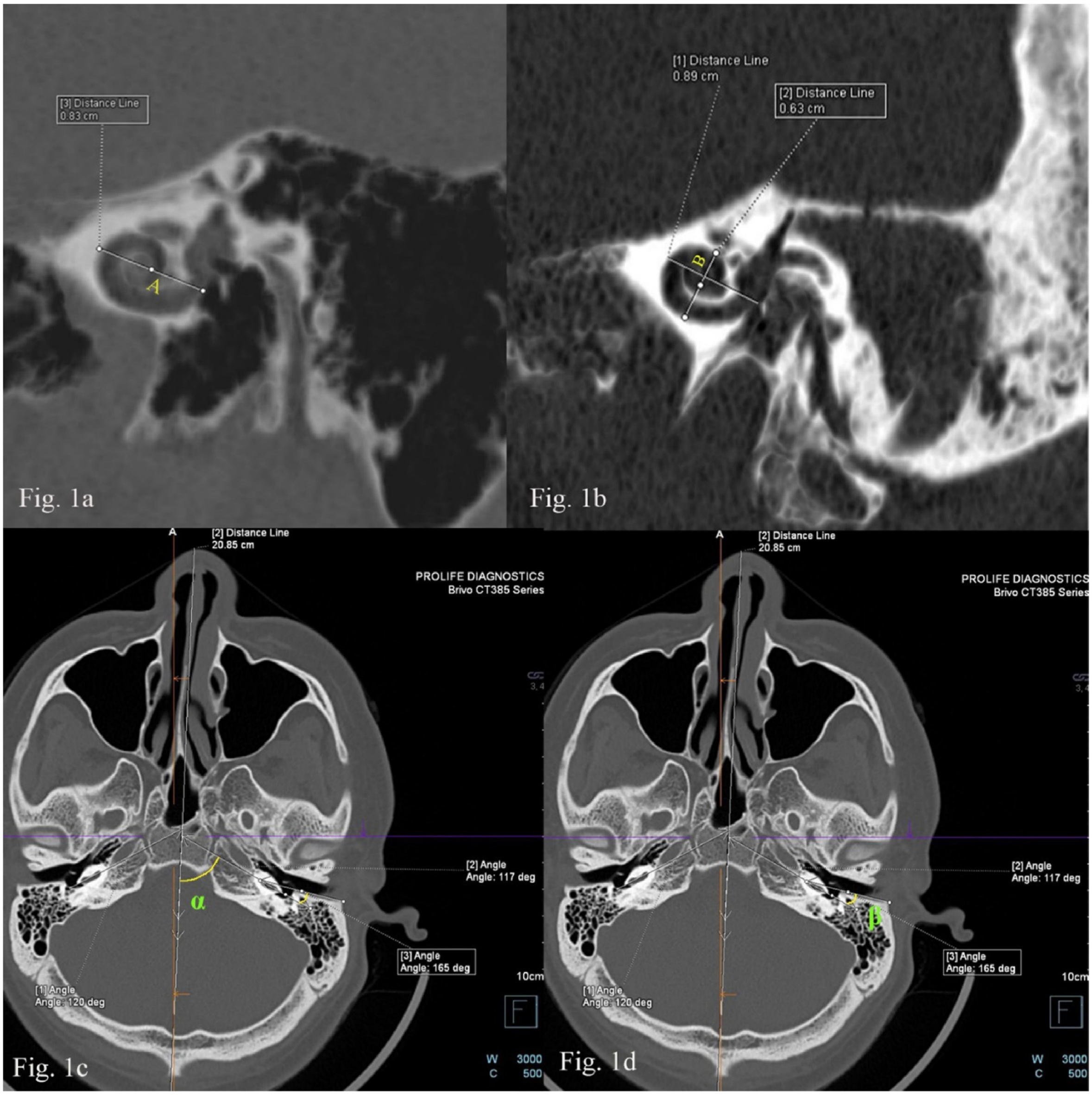


**Fig. 1.** Fig. 1a shows the measurement of A value, the largest distance from the centre of the round window to the lateral wall of the cochlea passing through the modiolus in the oblique sagittal reconstruction of the cochlea. Fig. 1b shows the measurement of the B value, a line drawn perpendicular to the "A" value passing through the modiolus in the oblique sagittal reconstruction of the cochlea. Fig. 1c alpha angle(α), the angle between the mid-sagittal plane and the long axis of the basal turn of the cochlea in the axial section, and Fig. 1d show the measurement of beta angle(β), the angle between the long axis of the cochlea and the surgical axis (the line passing along the posterior wall of the external auditory canal) on the axial section on CT scan.

the P-value was 0.349. The comparison of the Alpha and Beta angles on the right and left sides yielded a P-value of 0.256 and 0.983, respectively.

A similar comparative was carried out for A value, B value, CDL, 2 T CDL, alpha angle, and beta angle measured on the MRI scan between the right and left side. The mean A value on the right side was 7.968, and on the left side was 8.096 with a P-value of 0.661. The mean B value on the right side was 6.196 mm, and on the left was 6.243 mm, with a P-value of 0.791, which is not significant. The cochlear duct length measured in MRI was 29.208 mm on the right and 29.744 mm on the left, with a P-value of 0.628. The two-turn cochlear length measured on the right side was 25.483 and 26.149 on the left, with a P– P-value of 0.510. Both right and left alpha and beta angles were comparable, with a P-value of 0.807 and 0.898, respectively.

The diameter of the cochlear nerve was measured on an MRI scan only. The mean cochlear nerve diameter measured on the right side was 0.719 mm and 0.768 mm on the left side, with a P-value of 0.335. The cochlear nerve diameter was compared among males and females, and no statistically significant difference was found.

Since the results showed no significant difference between the values measured in the left and right ear on both the CT and MRI scans, we combined the value of the differences obtained in the A value, B value, cochlear duct length, and two-turn cochlear length in the right and left ear to derive a total of 94 ears. The mean, median, mode, and range of the values are given in Table 2.

All values measured in CT and MRI scans were combined and compared according to sex into males ($n = 24$) and females ($n = 22$). No statistically significant difference was noted based on sex.

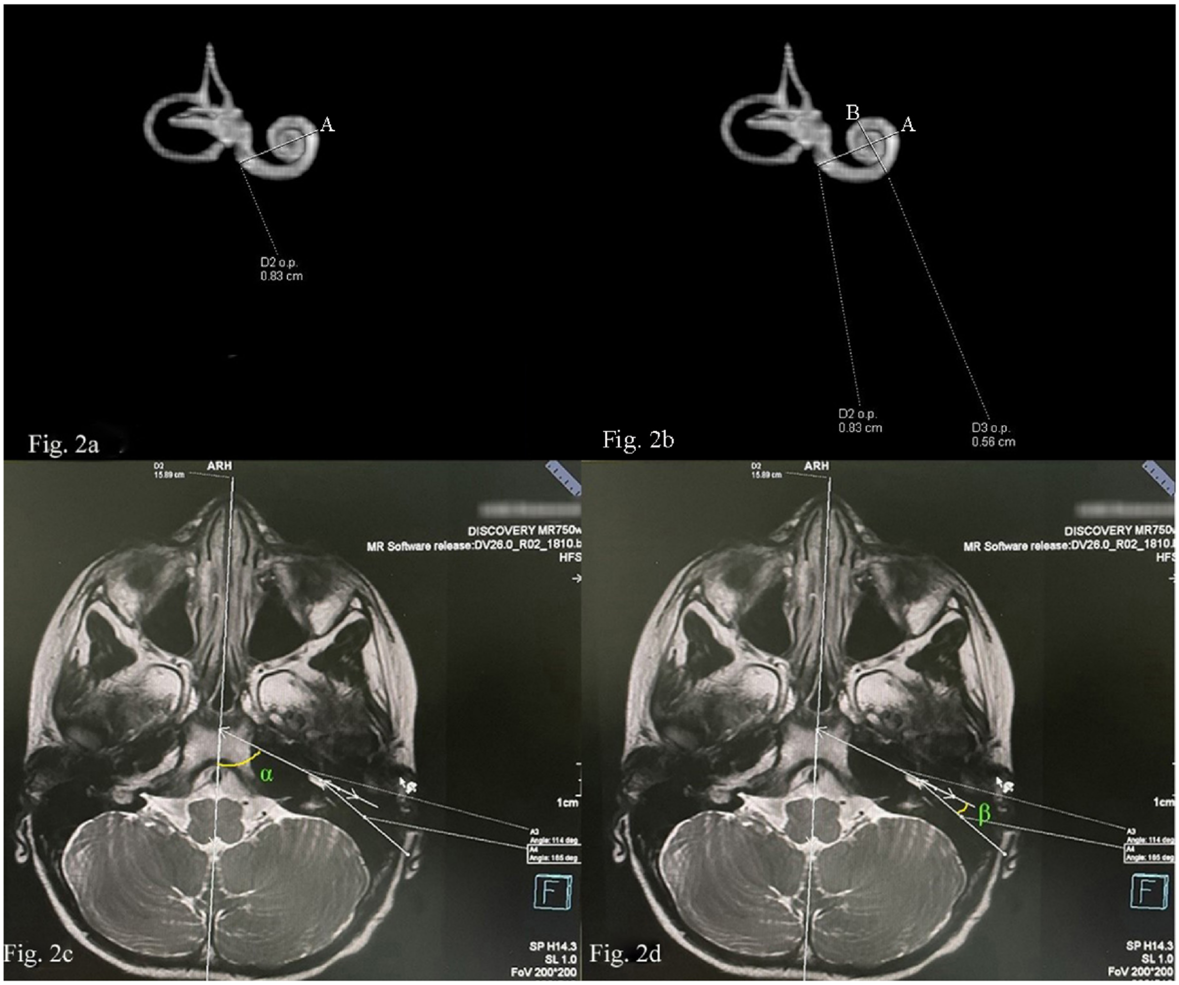


**Fig. 2.** Fig. 2a shows the measurement of A value, the largest distance from the centre of the round window to the lateral wall of the cochlea passing through the modiolus in the oblique sagittal reconstruction of the cochlea. Fig. 2b shows the measurement of the B value, a line drawn perpendicular to the "A" value passing through the modiolus in the oblique sagittal reconstruction of the cochlea. Fig. 2c Shows the alpha angle(α), the angle between the mid-sagittal plane and the long axis of the basal turn of the cochlea in the axial section and Fig. 2d shows the measurement of the beta angle(β), the angle between the long axis of the cochlea and the surgical axis (the line passing along the posterior wall of the external auditory canal) on the axial section on the MRI scan.

The corresponding author performed all surgical procedures and all had complete electrode insertion. No insertion-related issues were encountered in any of the patients.

## 5. Discussion

HRCT of the temporal bone is regarded as the most reliable method for determining cochlear measurements. However, physiologically, the electrode lies along or in the vicinity of the organ of Corti. Therefore, measuring the cochlear duct length based on the organ of Corti could yield more accurate results than the lateral wall. This physiological accuracy is better captured by MRI scans, which precisely assess the cochlea's active component. Moreover, the radiation-related concerns associated with CT scans, highlighted in a study by Pearce et al. in 2012, demonstrate a link between CT scanning in children and subsequent brain tumour and leukaemia development (Pearce et al., 2012). This concern is magnified with the growing early implantation trends.

Contrasting with CDL, measuring the two-turn cochlear duct length aids in electrode size selection for recipients because the basal turn and middle turn predominantly constitute the active cochlea. In contrast, the apical turn contributes to less than 15%. The narrower diameter of the apical turn raises concerns over potential trauma from electrode insertion, contradicting the hearing preservation concept (Alenzi et al., 2021).

### 5.1. The difference in values measured on CT and MRI scans

Our study showed no significant difference in cochlear measurements on CT scans between the right and left side or between male and female subjects. These findings are similar to other studies reported in the existing literature (Taeger et al., 2021; Zahara et al., 2019; Grover et al., 2018).

The mean value of CDL measured on CT scan was 30.13 ± 5.25 mm in the right ear and 30.95 ± 2.70 in the left ear, comparable to the finding from the Indian population by Grover et al. (2018).

Koch et al. (2017), reviewed various modalities for measuring cochlear duct length. They concluded that the measurement of CDL on CT scan has been focused on the lateral wall (LW), whereas MRI scans measure at the level of the organ of Corti (OC) which is more physiological.

Our analysis found no statistically significant difference in cochlear measurements between CT and MRI scans (Table 2). This is consistent with a previous study by Nash et al. (2019), which found a mean error of 0.26 mm between CT and MRI measurements of the

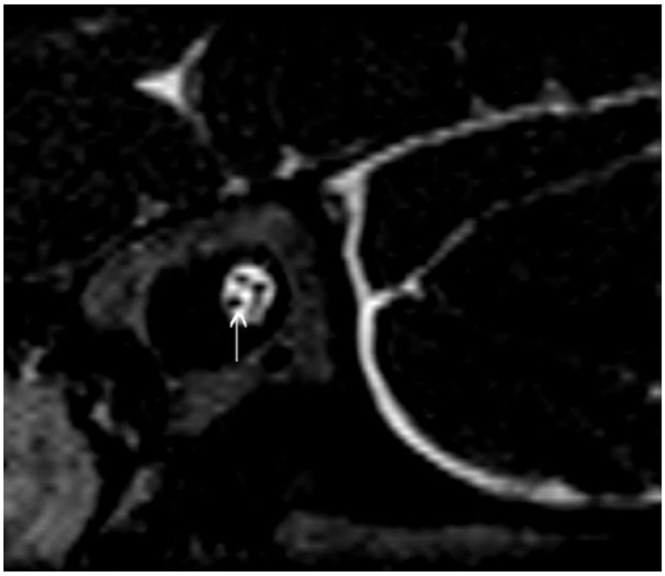

**Fig. 3.** White arrow shows Cochlear nerve in oblique sagittal reformatted image on heavily T2WI MRI scan.

A value. However, our study found a mean difference of 0.567 + 0.413 mm between MRI and CT A values, which suggests that MRI may be slightly more accurate than CT for measuring the A value.

Conversely, JF Thong et al. (2017) conducted a study comprising 157 patients, where the mean A value exhibited a notable difference between the male and female groups within the population. The racial diversity of the study population, including Chinese, Malay, and Indian population might have contributed to the significant difference in the results. The average values obtained also varied from other studies conducted in different geographical locations. This emphasizes the need for race-specific standardized data for future reference.

On comparing the value of the alpha and beta angles between CT scans and MRI scans, no significant differences were observed indicating that both CT or MRI scans are viable options for measuring cochlear angles and thus minimizing the exclusive requirement for a CT scan.

In the study by S Sharma et al. (2018) a correlation was found between alpha angle and difficulties during implant electrode insertion. As their patients with an alpha angle of less than 50° had difficulties in implant electrode insertion. In contrast, our study observed that all implanted individuals had an alpha angle exceeding 50°, facilitating uncomplicated implant insertions.

**Table 1**
Comparison of values measured in the right and left ear on CT and MRI scans. (DF-degree of freedom, N-number, mm-millimetre).

| | Group | | Mean value | Standard Deviation | t values | DF | P value |
|---|---|---|---|---|---|---|---|
| **CT Scan** | A Value | Right | 8.191 | 1.383 | −1.005 | 92 | 0.317 |
| | | Left | 8.415 | 0.638 | | | |
| | B value | Right | 6.313 | 0.628 | 0.331 | 92 | 0.741 |
| | | Left | 6.270 | 0.619 | | | |
| | Cochlear Duct | Right | 30.131 | 5.249 | −0.955 | 92 | 0.342 |
| | | Left | 30.953 | 2.699 | | | |
| | Two-turn length | Right | 26.323 | 4.629 | −0.942 | 92 | 0.349 |
| | | Left | 27.036 | 2.341 | | | |
| | Alpha angle | Right | 62.596 | 10.477 | −1.143 | 92 | 0.256 |
| | | Left | 64.702 | 7.055 | | | |
| | Beta angle | Right | 16.000 | 4.863 | 0.021 | 92 | 0.983 |
| | | Left | 15.979 | 4.766 | | | |
| **MRI scan** | A Value | Right | 7.968 | 1.370 | −0.440 | 92 | 0.661 |
| | | Left | 8.096 | 1.439 | | | |
| | B value | Right | 6.196 | 1.087 | −0.266 | 92 | 0.791 |
| | | Left | 6.243 | 0.551 | | | |
| | Cochlear Duct Length | Right | 29.208 | 5.201 | −0.486 | 92 | 0.628 |
| | | Left | 29.744 | 5.504 | | | |
| | Two-turn Cochlear Duct Length | Right | 25.483 | 4.556 | −0.661 | 92 | 0.510 |
| | | Left | 26.149 | 5.192 | | | |
| | Alpha angle | Right | 62.426 | 9.835 | −0.246 | 92 | 0.807 |
| | | Left | 62.936 | 10.315 | | | |
| | Beta angle | Right | 14.745 | 4.131 | 0.129 | 92 | 0.898 |
| | | Left | 14.617 | 5.375 | | | |
| | Cochlear nerve diameter (mm) | Right (N = 43) | 0.719 | 0.244 | −0.969 | 92 | 0.335 |
| | | Left (N = 44) | 0.768 | 0.246 | | | |
| | Cochlear nerve diameter Right ear (mm) | Male (N = 23) | .80 | .109 | 0.924 | 41 | 0.361 |
| | | Female (N = 20) | .77 | .103 | | | |
| | Cochlear nerve diameter Left ear (mm) | Male (N = 24) | .81 | .167 | −0.607 | 42 | 0.547 |
| | | Female (N = 20) | .84 | .114 | | | |

**Table 2**
Shows differences between values measured on CT and MRI scans.

| Value calculated | Mean(mm)+SD | Median(mm) | Mode(mm) | Range of difference (mm) |
|---|---|---|---|---|
| A Value | 0.567 + 0.413 | 0.8 | 1.1 | 0–1.4 |
| B Value | 0.405 + 0.368 | 0.4 | 0 | 0–1.5 |
| Cochlear duct length | 2.365 + 1.675 | 2.46 | 2.5 | 0–5.78 |
| Two turn length | 2.063 + 1.477 | 1.81 | 1.1 | 0–5.11 |

**Table 3**
Mean values of cochlear measurements obtained in our study pertaining to the Indian population.

| Value measured(mm) | On MRI scan(mm) | On CT scan(mm) |
|---|---|---|
| A value | 8.096 ± 1.439 | 8.45 ± 1.638 |
| B value | 6.243 ± 0.551 | 6.270 ± 0.619 |
| Cochlear duct length | 29.74 ± 5.5 | 30.953 ± 2.69 |
| Two-turn cochlear length | 26.149 ± 5.192 | 27.036 ± 2.34 |
| Cochlear nerve diameter | 0.77 ± 0.246 | NA |

**Cochlear nerve diameter:** The cochlear nerve diameter measurement was conducted on 43 children. In the remaining cases, visualization of the nerve was hindered by motion artefacts causing blurred images and a lack of high resolution.

The mean value of the cochlear nerve diameter measured on the right side was 0.719 ± 0.24 mm, and on the left side was 0.768 ± 0.246 mm, with no significant difference between the two sides($p = 0.335$). We also compared the diameter of the cochlear nerve among male($n = 23$) and female($n = 20$) populations. No significant difference was observed in the diameter of the cochlear nerve between the male and female populations on both the right ($p = 0.361$) and left ear($p = 0.547$).

The measured values of cochlear nerve diameter, in our study were less compared to a study done by Jaryszak et al. (2009), which is a retrospective review of MRI images for the measurement of cochlear nerve diameter in 30 patients by two independent blinded observers. In this study (Jaryszak et al., 2009), the CN vertical diameter was 1.4 ± 0.21 mm, the horizontal diameter was 1.0 ± 0.15 mm, and the cross-sectional area was 1.1 mm ± 0.26mm2. These differences in measurements might be attributed to Jaryszak et al. (2009) studying the American population, while our research exclusively involved Indian subjects.

In 1992, Nadol et al. (Nadol and Xu, 1992) measured the cochlear nerve diameter in 47 cadaveric temporal bones (which were fixed and dehydrated). The mean diameter of the cochlear nerve was determined to be 1.04 ± 0.11. This measurement exceeded our study's mean cochlear nerve diameter, with no significant difference between male and female temporal bones.

Cochlear nerve diameter measurement's precision could be enhanced by employing a 3 T MRI scan, which could be considered for future comparative investigations.

Dimensions of the cochlea and cochlear nerve exhibit regional and racial variations (Grover et al., 2018). Therefore, establishing our standardized values are crucial for diagnosing cochlear hypoplasia and other inner ear deformities. The below table summarises our data (Table 3).

## 6. Conclusion

Using only MRI scans in the hands of experienced centres decreases the radiation risk for children and the financial burden on the program. In our study, A, B, CDL, and 2-turn CDL values are comparable, and there is no significant difference between CT and MRI measurements. The mean difference in the A value is 0.567 ± 0.413 mm, the B value is 0.406 ± 0.368 mm, and CDL is 2.365 ± 1.675 mm ($p > 0.05$). The MRI scan can serve as the exclusive radiological investigation in pediatric cases, while the CT scan can be reserved for complicated cases with complex inner ear deformities.

MRI scan provides a more functional representation of the cochlea, measuring the length along the Organ of the Corti.

The anticipation for difficult and partial insertion based on alpha and beta angles are comparable in both modalities, providing an additional advantage.

## Financial disclosure

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Declaration of competing interest

There are no conflicts of interest among the authors.

## Acknowledgement

We thank all the participants and their parents for participating in the study.

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