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Original Research Article

Measuring cochlear duct length in North Indian population: a detailed study

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ABSTRACT

Background: The cochlea is a shell-like structure of the inner ear which is comprised of two canals (the Scala vestibule and the Scala tympani) and the Organ of Corti. Cochlear duct length is defined as the length of the scala media as measured from the middle of the round window to the helicotrema. Preoperative measurement of CDL is significantly important if the desired intracochlear electrode array placement is required.
Methods: This retrospective study was done in Mehrotra ENT Hospital, Kanpur, India, which is a tertiary care hospital and referral centre for cochlear implants. We included 800 patients (400 males and 400 females) in the study with bilateral hearing loss who were evaluated for cochlear implantation. HRCT temporal bone of these patients were analyzed and a variable A was measured.
Results: Our study included 800 patients, Mean of distance A value for male children is 7.94mm (range 7.0-9.2mm). Mean of distance A value for female children is 7.72mm (range 6.95-8.8mm). So the overall average is 7.83mm. We calculated cochlear duct length using the formula, CDL=4.16A-3.98. The mean cochlear duct length was 28.6mm with a range from 24.9-34.3mm.
Conclusions: Our study is one of the most detailed large (800 cases) study of cochlear duct length in the North Indian population. Our results suggest that an average smaller cochlear duct length in our geographical area is a significant finding in the understanding of cochlear anatomy and physiology. It will have great importance on the insertion depth in cochlear implantation.

Keywords: Cochlear duct length, Cochlear implantation, High-resolution computed tomography

INTRODUCTION

The anatomy of the cochlea is the most significant factor for successful cochlear implantation. Cochlea anatomy is variable in humans so measuring cochlear duct length forms the basis for better cochlear implant results. Cochlear duct length (CDL) is defined as the length of the scala media as measured from the middle of the round window to the helicotrema.

Precise knowledge of CDL is quite important if desired intracochlear electrode array placement is required and residual hearing is to be preserved. Also, now due to the advancement in cochlear implants variable lengths of electrodes are available in the market for implantation and reports of incomplete insertion of the longer electrodes, variability of the length of cochlear duct can be a significant variable in the depth of insertion. So preoperative estimation of CDL and precise insertion of electrode array can go a long way in cochlear implantation

and thus helping patients in preserving residual hearing thus leading to better hearing. Measurement of the CDL has been performed radiographically. At our centre routinely, all patients with congenital hearing loss undergo high-resolution computed tomography (HRCT) of temporal bone during workup for cochlear implantation. HRCT gives very precise quantitative information about anatomy and morphology, especially through three-dimensional (3D) reconstructions. With the help of software and mathematical formulae, we can calculate the length of the cochlear duct. Our study deals with the Asian race specifically the North Indian race, who have smaller skulls. The aim of our study is to collect significant data regarding the CDL in the North Indian population so this knowledge can be applied by surgeons to know preoperatively about the insertion depth of the electrode array and it helps in the precise placement of the cochlear implant for better hearing and preserving the residual hearing function in patients.[1]

METHODS

This retrospective study was done in Mehrotra ENT Hospital, Kanpur, India, from May 2016 to May 2023 which is a tertiary care hospital and referral centre for cochlear implants. The statistical method and tools used for the sampling and study: Fischer's Exact Test

Inclusion and exclusion criteria

Patients who were under 5 years of age and Patients with congenital bilateral severe to profound SNHL were included. Patients above 5 years of age and Patients with unilateral severe to profound SNHL were excluded.

Sample size and sampling procedure

Our study included 800 patients (400 males and 400 females) who were evaluated for cochlear implantation. The patients were grouped into male and female. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. HRCT temporal bones of all the children less than 5 years of age, with congenital bilateral severe to profound SNHL who were being worked up for cochlear implants, were studied and analyzed. General Electric (GE) CT machine with 128 slices was used on all these patients. A view of the basal turn of the cochlea was made which showed one full turn of the cochlea from the round window onwards. As it is not possible to visualize the entire basal turn of the cochlea using a single two-dimensional plane, reconstruction was performed using a 1-mm layer, minimum intensity projection. This cut showed the entire basal turn of the cochlea, round window, oval window, and anterior parts of superior and lateral semicircular canals. In this view, the largest distance from the round window to the lateral wall of the cochlea, through the modiolus was calculated (*A*) (Fig 1). For the same ear, this distance was calculated independently by two radiologists, and an average was taken for both values. In none of the cases was the difference of these two values more than 0.2 mm. Cochlear duct length was calculated for both sides in all patients. The formula used to calculate this was;

$$CDL = 4.16A - 3.98$$

Where CDL is Cochlear duct length and *A* is the measured largest distance from the round window to the lateral wall of cochlea passing through modiolus.[1]

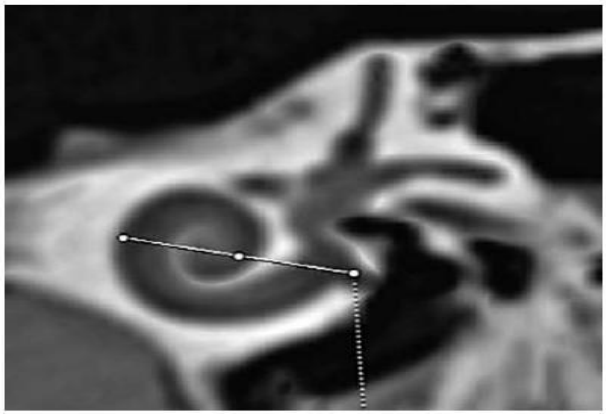

Figure 1: Measurement of the variable 'A' in double oblique reformatted computed tomography (CT) images. The variable 'A' was measured from the center of the round window to the farthest point on the opposite wall of the cochlea passing through the modiolus in the minimum-intensity projection (minIP) mode of the reformatted image.

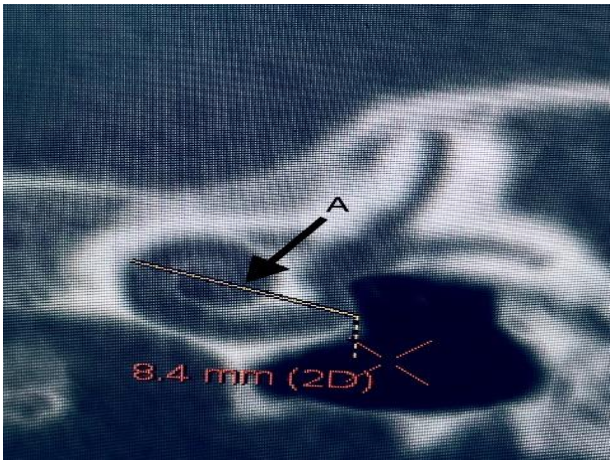

Figure 2: Evaluation of cochlear duct length using the formula CDL = 4.16A–3.98. HRCT image shows distance A (arrow) from the center of the round window to the far most extension of the basal turn, which measures 8.4 mm. According to the formula, the cochlear duct has a length of 30.96 mm.

RESULTS

Our study included 800 patients (400 males and 400 females) who were evaluated for cochlear implantation without any vestibulocochlear anomaly.

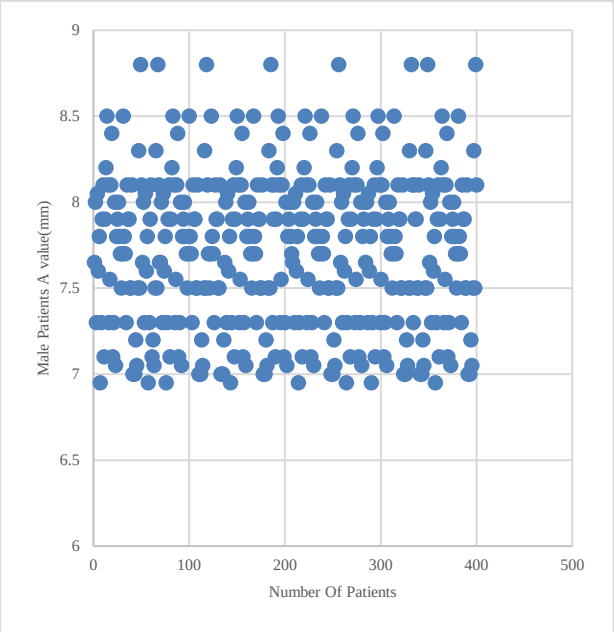

Figure 3: Scatter diagram depicting the value of A in male patients.

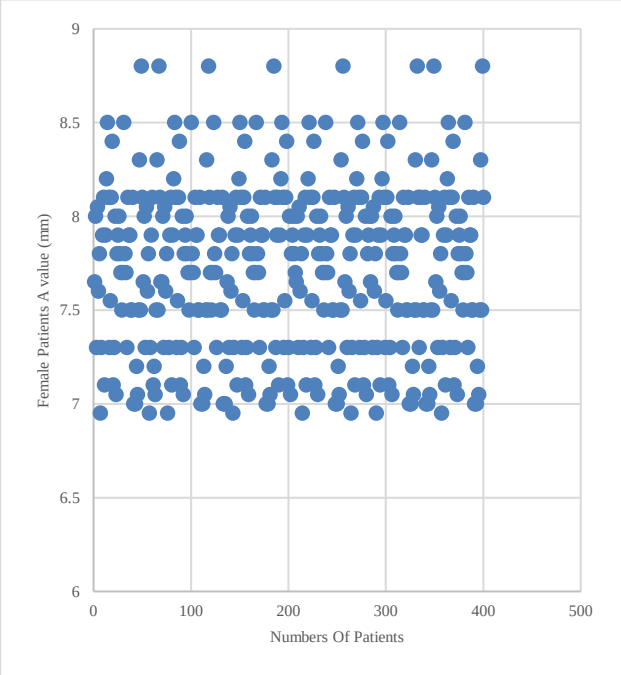

Figure 4: Scatter diagram depicting the value of A in female patients.

HRCT temporal bones of these patients were analyzed and results were evaluated. Data collected from 800 patients were used to calculate the A value and which was used to measure the cochlear duct length. Mean of distance A value for male children is 7.94 mm (range 7.0-9.2 mm) (Right Ear-7.95 mm, Left Ear- 7.93 mm). Mean of distance A value for female children is 7.72 mm (range 6.95-8.8 mm) (Right Ear-7.71 mm, Left Ear- 7.72 mm). So, the overall average is 7.83 mm. We calculated cochlear duct length using the formula, CDL=4.16A-3.98. The mean cochlear duct length was 28.6mm with a range from 24.9 to 34.3 mm.

DISCUSSION

The cochlea was discovered in 1552 by Bartholomeus Eustachius and denoted as cochlea in 1561 by Gabriel Falloppio.[2] The human cochlea is fully formed at birth, and the length of the human cochlear duct has been previously considered to be roughly 34 mm.[3] However, the distribution of the CDL in the population shows great variability due to gender and ethnic factors.[4,5] The human cochlea exhibits extensive anatomic variations. These variations influence the location of cochlear implant electrodes and affect the potential of hearing preservation surgery. Cochlear duct length is used to design the precise cochlear implant electrode array.[6]

There have been numerous studies on measuring the cochlear duct length to know the variability in the size of the human cochlea but the first documented record of CDL estimation was made by Hensen in 1865 by direct histologic measurements at the location of the organ of Corti using micrometers.[7] The length was determined to be 33.5 mm in this case. However, the first landmark study using indirect methods to plot a two-dimensional (2D) graphical representation of the histologic sections was published by Hardy in 1938 in 68 samples.[8] The mean length was of 31.52 mm, and the variation was of around 10 mm. Multiple studies have been performed both in temporal bone histology and HRCT temporal bone.[9] Our study is centered on radiologically (HRCT temporal bone) and in North Indian Population.

Measurement of the CDL can be valuable in the preoperative stage of cochlear implantation. It is particularly important when precise intracochlear placement of electrodes is desired. In patients with no residual hearing, the aim is to insert the electrode array as deep as possible to achieve full coverage of the sensory range. In contrast, in patients with residual hearing, electrode arrays are designed to be placed only partially within the cochlea allowing electroacoustic stimulation.[10] Now, with the advancement of hybrid technology or electro-acoustic stimulation (EAS), the precise insertion of the electrode array inside the cochlea to achieve acoustic perception at high frequencies, while avoiding deeper insertions to avoid intracochlear trauma, has become of prime importance. Speech perception depends on pitch-matching between the frequency stimulation being delivered by the cochlear implant electrode and the tonotopically mapped area of the cochlea receiving the stimulus. Many studies have suggested that the substantial

variation is found in human cochlear lengths implies that significant differences may exist in intracochlear frequency distribution.[11] For cochlear implant recipients, understanding inter-individual frequency variations may be crucial. Almost all the studies which have been done for estimating cochlear duct length are from the Western world where skull size and intracranial structures are larger than from the Indian subcontinent. It was important for us to study the length of the cochlea in the North Indian population and give detailed results based on the Indian population. In a study by Ulehlová et al they studied a group of 50 cochleae from 28 men aged 38-73 years, and great variability in the length of the cochlear duct was found ranging from 28.0 to 40.1 mm.[12] In our study, we found mostly shorter cochlea with a maximum length of up to 34.3 mm. Sato et al did an interesting study in nine pairs of temporal bones from age-matched male and female individuals (1 day to 76 years old) using a computer-aided three-dimensional reconstruction and measurement method.[13] The mean cochlear length was significantly longer in males (37.1±1.6 mm) than in females (32.3±1.8 mm). They postulated that sexually dimorphic cochlear length may pose a new issue in auditory physiology in humans. Ketten et al applied 3D reconstructed CT of the spiral canal of the cochlea in 20 patients in whom a Nucleus R cochlear implant was placed; the mean measured spiral canal length was 33.01±2.31 mm in 3D CT, and the mean attained electrode depth was 20.19±2.86 mm.[14] It was interesting to see that length of the cochlear duct was less in our study. This could be due to the smaller size of human skulls in this geographical area. The smaller size of the cochlea has implications in understanding hearing physiology. The frequency position map would be different for cochlea of different lengths, whether smaller or larger. A smaller length of cochlea would imply a comparatively crowded distribution of frequencies along the cochlear length.[15] Similarly, a longer cochlear duct would mean a wider distribution of frequencies, so that an average smaller length of cochlea should necessitate a lesser insertion depth of electrode array of the cochlear implant. Also unknowingly, with the placement of a current electrode array into a smaller skull with shorter cochlear duct length inadvertent damage to the delicate inner ear structures may occur.[16]

Limitations

Current study has some limitations, the inclusion of only children aged 0-5 years. However, it is well described in the literature that the length/height of the children's cochlea does not change after birth.[17] Hence, the age factor should not preclude extending the results to the adult population. The results of our study are in unison with the previously-published studies in the literature documenting the ethnic variability in the CDL.[18]

CONCLUSION

Current study is one of the most detailed large (800 cases) study of cochlear duct length in the North Indian population. Our results suggest that an average smaller cochlear duct length in our geographical area is a significant finding in the understanding of cochlear anatomy and physiology. It will have great importance on the insertion depth in cochlear implantation. Presently, Surgeons do not consider cochlear duct length as a factor influencing the results of cochlear implantation. We suggest that CDL measurement should be made a crucial part of the preoperative workup for cochlear implantation and ultimately electrode array length should be tailor-made for every individual for better hearing results.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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