MEASUREMENT OF COCHLEAR DIMENSIONS BY 3D CT-MRI AND ITS UTILITY IN COCHLEAR IMPLANTS SURGERY

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ABSTRACT

BACKGROUND

We presented role of MDCT and high-field MRI in cochlear dimension before the cochlear implantation. In our institute, we used combo modality as HRCT and high-field MRI rather to use single modality for complete workup and for the selection of proper size electrode array.

The aim of the study is to correlate the cochlear dimensions using CT/MRI with- (1) Intraoperative surgical findings/difficulties. (2) Preoperative electrode array option selection.

MATERIALS AND METHODS

MDCT and 1.5 Tesla MRI machine was used to scan the patients. Patients screened and operated at B.J. Medical College and Civil Hospital, Ahmedabad, Gujarat. 30 patients were taken within period of 2 years from March 2009 to April 2011. All the patients underwent CT and MRI study. Cochlear implant (MED-EL, Austria) was used for this study. Each scan was obtained on a 16-section spiral CT (GE, bright speed). The studies were performed with the following parameters- 0.75-mm collimation, 0.625-mm section thickness, 140 kVp, 120 mAs, pitch of 0.8, a 15-cm field of view and a 512 x 512 matrix. The initial data sets were then reconstructed at 0.1 mm intervals.

All 15 patients also underwent MRI (GE Signa HDx 1.5T series) examination for internal auditory canal in whom FIESTA sequence was taken with flip angle 65 degrees, slice thickness 0.8 mm, matrix 256 x 320.

RESULTS

Thirty cases were taken for the study. Twenty patients were completely suitable for standard electrode. Six patients needed the use of insertion test device before the actual insertion of active electrode. In 3 patients, split electrode was kept as backup implant, but was finally not needed. One patient had common cavity cochlea who refused surgery because of variable outcome. Three patients had high jugular bulb. Six patients had rotated cochlea. One patient had dehiscent facial nerve at 2nd genu.

CONCLUSION

Multidetector volumetric CT scanner with 3D reconstruction and higher strength MRI provide soft tissue and bony detail with very high resolution for cochlea and also helps in minimise the intraoperative difficulties and overcoming it and also help in assessing the involvement of adjacent critical structures like internal carotid artery, jugular bulb and facial nerve.

KEYWORDS

Cochlea, Cochlear Measurement, HRCT, High-Field MRI, Electrode Array, Cochlear Implant.

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BACKGROUND

Cochlear implants were introduced commercially in 1972. These devices stimulate the auditory nerve directly when placed in the cochlea (tympanic ramp).[1]

Cochlear implants are used recently in patients having hearing loss, whether congenital or acquired cause, so it is very important for the implant surgeon and for the radiologist to have detailed knowledge of the cochlear cavity, which is location for the active electrode of implant. In present time, Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) used as combined modality in preoperative workup of the cochlear implant patients.

MDCT is best for the bony labyrinth and high-field MRI for the membranous labyrinth and for the assessment of the vestibulocochlear nerve. 3D reconstruction in MDCT and high field MRI is very helpful for cochlear turns and to detect cochlear anomalies (Figure 1). The surgery for the cochlear implantation is common in present era and one of the most successful surgical procedure in congenital and acquired sensorineural deep hearing loss particularly in those patients who have not responded well to medical treatment. As a cochlear implant surgeon and as a radiologist, it is most important to understand the imaging findings, which contraindicate the surgery like complete labyrinthine agenesis, cochlear nerve agenesis and cochlear ossification.

MDCT with 3D reconstruction after cochlear implantation is very helpful to know the position of the active electrode into the cochlear canal (Figure 2).

MATERIALS AND METHODS

MDCT and 1.5 tesla MRI machine was used to scan the patients. Patients screened and operated at B.J. Medical College and Civil Hospital, Ahmedabad, Gujarat.

30 patients were taken within period of 2 years from March 2009 to April 2011. All the patients underwent CT and MRI study. Cochlear implant (MED-EL, Austria) was used for this study.

HRCT scanning is performed on 16-slice MDCT (GE) in the standard axial plane with helical technique (120 kV, 350 mA, pitch of 0.85, rotation time of 1 second, section thickness of 0.6 mm, matrix of 512 x 512).

MR scanning is performed with following sequences. 3D CISS was performed with these parameters: 10-cm FOV, TR/TE of 8/4, 32 sections of 1-mm thickness, 256 x 256 matrix, flip angle of 45°, bandwidth of ±32 kHz, two phase cycles and an acquisition time of 2 minutes 24 seconds. Phase-cycling involved two 3D steady-state datasets acquired sequentially, each with a specific radiofrequency phase shift added at every TR.

Aims of the Study was-

- To study the dimensions of cochlea on CT and MRI.
- To correlate the cochlear dimensions using CT/MRI with- (1) Intraoperative surgical findings/difficulties.
  (2) Preoperative electrode array option selection.
- Information an implant surgeon wants from reporting radiologist.
- To identify absolute and relative contraindication for implantation.

RESULTS

30 cases were taken for the study. 20 patients were completely suitable for standard electrode. 6 patients needed the use of insertion test device before the actual insertion of active electrode. In 3 patients, split electrode was kept as backup implant, but was finally not needed. One patient had common cavity cochlea who refused surgery because of variable outcome. Three patients had high jugular bulb. Six patients had rotated cochlea.

One patient had dehiscent facial nerve at 2nd genu.

In our study, we did CT and MRI in all the patients. MRI was more helpful for membranous labyrinth and CT for the bony labyrinth. MRI was superior in assessing the patency of membranous labyrinth detected even smaller spiral canal sclerosis and obstruction. Vestibulocochlear nerve was well assessed on MRI. CT was very helpful in assessing the bony wall of the cochlea. We were able to put proper size electrode array after 3D CT and 3D MRI.

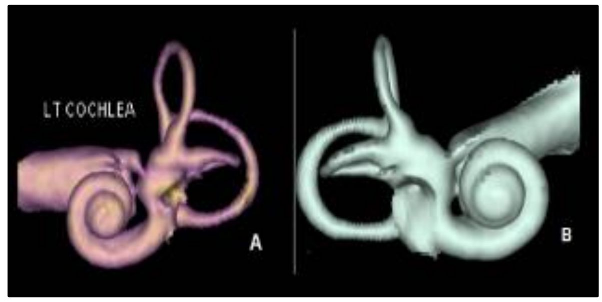

Figure 1. 3D CT Image A and B Showing Well-Defined Apical, 2nd and Basal Turn of Cochlea

Figure 2. 3D Colour Coded Post Cochlear Implantation Images Showing Active Electrode within the Cochlear Cavity

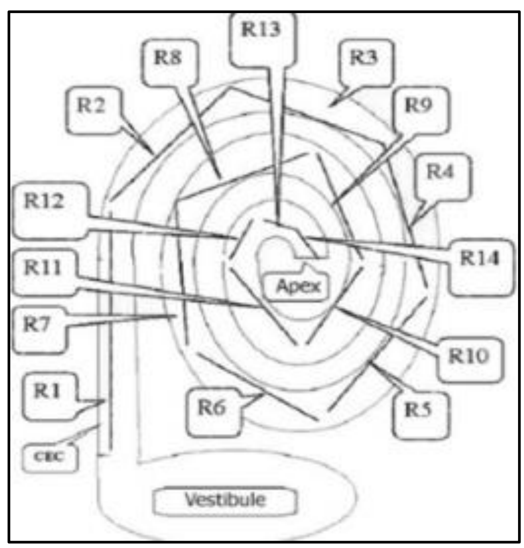

Figure 3. Schematic Drawing Showing 3D Magnetic Resonance Imaging Measurement were Done. R = Measurement between Two Points in the Spiral Canal of Cochlea, Measurements were Done from the Vestibule Towards the Apex of the Cochlea, Using 2 mms Predefined Measures for the First Six Measurements (R1, R2, R3, . . . R6)

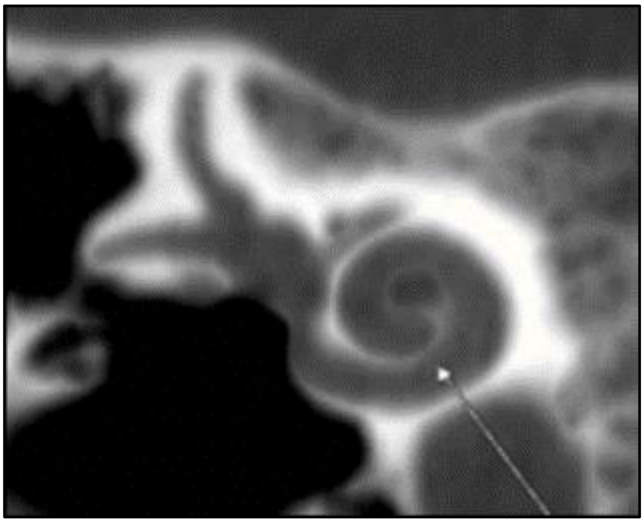

Figure 4. MDCT with MIP Image Showing Apical, 2nd and Basal Turn of Cochlea

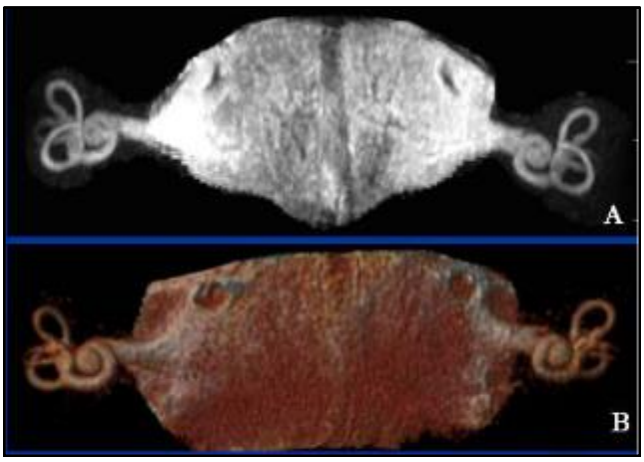

Figure 5. (A and B) MRI 3D Reconstruction with Colour Coded Image Showing Well Delineation of Turns of Cochlea for Cochlear Length Measurement

Figure 6. MRI 3D Reconstruction Magnified Images with VRT Images for Accurate Cochlear Length Measurement with Placement of the Predefined Measurements on Segmental Part of Cochlear Canal

MRI 3D reconstruction coronal image showing basal turn, second turn and apical turn of cochlea with detailed evaluation of the anatomy for the cochlear length measurement.

DISCUSSION

Cochlear implant were introduced commercially in 1972. These device stimulate the auditory nerve directly when placed in the cochlea. As these devices are currently being used more often for the treatment of patients with hearing loss, knowledge about the anatomy of the spiral canal of cochlea into which the electrode is placed has become paramount. CT and MRI are currently used for the evaluation of anatomical status of the cochlea.

Cochlear canal is very well seen on CT scan and MRI. MRI is better than CT scan in detecting the early changes of fibrosis in perilymphatic space. MRI is mandatory preoperatively to exactly demonstrate the perilymphatic fluid, which is reflected as bright signal on MRI, if any patchy hypointensity in perilymphatic fluid on MRI, then always suspects early fibrosis, when CT turns out absolutely normal. Cochlear fibrosis detection is important because cochlear implant surgeon decides the length of electrode array as per the normal length of the cochlear canal.

In our study, we measure the cochlear dimension manually over the best cochlear section. It is taken at basal part near the round window at vestibular end. It is taken at 2nd turn as well as at the apical turn on CT MIP image (Figure 4) and on MRI 3D reconstruction with VRT images (Figure 5 and Figure 6).

MRI 3D reconstruction coronal image is the best choice for the clear delineation of the cochlear turns. We used coronal 3D reconstruction image of the MRI for taking measurement of the cochlea. On the basis of cochlear length measurement on CT and MRI images, cochlear implant surgeon can select the length of the electrode array and can put the exact size electrode array in hearing loss patient during surgery.

Another way of measuring cochlear dimension- Length of cochlea is measured first by using digitised ruler images (in millimetres), which are part of the computer software, projected onto the cochlear images. The length of the spiral canal of cochlea is measured from its closer point to the vestibule to its apex. Divide the spiral canal into a number of section and to measure each one; adding up these values yielded the total length of cochlea.[1]

The rulers has predefined 2.0, 1.5 and 1.0 mm markings and are placed over the cochlear images for measurements. Many rulers are required for each image until reaching the apex of the cochlea. The first six ruler (R1 to R6) measured 2 mm, the next rulers has smaller sizes to measure the cochlear contours (R7 to R14)[1] (Figure 3).

In our study, HRCT detected all the cases with cochlear abnormalities as by MRI, however, it also detected two cases of labyrinthine ossification, which was not well apparent on MRI.

On the other hand, out of 7 patients declared normal by CT, MR detected one case of common VCN with absence of cochlear nerve and one case of labyrinthine fibrosis.

In 2 patients, CT shows only internal auditory stenosis in which MR reveals absence of VCN.

It is also crucial to notice dilated endolymphatic duct and sac preoperatively on MRI as hyperintense sac like signal at the level of common crus at the junction of posterior and superior semicircular canal with vestibule, whereas CT scan shows dilated vestibular aqueduct, which should be less than 1.5 mm in size or equal to the diameter of the axial cut of the posterior semicircular canal. It is important for the cochlear implant surgeon to keep ready for intraoperative CSF leak also known as gusher syndrome.

Casselman et al[2] were first to apply CISS-3DFT MRI (constructive interference in steady state-three-dimensional Fourier transformation magnetic resonance imaging) in the study of the inner ear and in the cerebellopontine angle. A study of 50 normal ears and 10 diseased ear showed detailed images of the cochlea, vestibule and semicircular canals as well as visualisation of the vestibule-cochlear nerve.

Silberman et al[3] studied 40 patients with cochlear implants and have shown the role of MRI, especially with deep hearing loss. These authors suggested that fibrosis maybe missed on CT scan, so using CT scan and MRI together as complement modalities as preoperatively in cochlear implants patients.

Jackler et al[4] found a 46% rate of false negative results when comparing the results of high resolution CT with surgical findings in 36 years with implants. Nikolopoulos et al)[5] concluded that the sensitivity rate was about 62.5% in a study of 108 children. The conclusion of these two papers have suggested that normal preoperative CT scan does not rule out the possibility of early fibrosis, which is only well appreciated on high-field MRI.

Ketten et al[6] studied the length of the spiral canal of cochlea preoperatively using CT scan and found that mean length of the cochlea was about 33.01 mms (standard deviation-2.31 mms). These values are more from those in our 3D MRI images (17 to 26.50 mms).

Guirado et al[7] applied CT and MRI of 30 patients with deep hearing loss and they found that condition like congenital inner ear malformation including Mondini deformity, fenestral and retrofenestral otosclerosis, semicircular canal agenesis, labyrinthine dysplasia and labyrinthine fibrosis and ossification. In one case, MRI picked up early fibrosis when CT was normal.[8]

Himi et al[8] studied 3D reconstructed CT of temporal bone for assessment for preoperative assessment in cochlear implant patients and claimed the benefits of 3D reconstruction in MDCT, however, MRI was superior in detecting early fibrosis in perilymphatic space. CT would be the choice in post cochlear implantation patients where MRI is contraindicate.

3D images in CT and MRI provide the information to the operating surgeon with anatomical structural information, which helps in cochlear implantation surgery and provide information for contraindication of implantation.[9]

Our 3D MRI image measurements were not similar to the values measured using CT in the abovementioned studies, which appear to provide measurements that are closer to the true size of the cochlea. In our cases, the size of the cochlea in the images was smaller. Additionally, due to an underestimated MRI measurement or true variability in the size of the cochlea in the temporal bones we studied.[6]

CONCLUSION

HRCT and high-field MRI imaging are essential for preoperative imaging of the cochlea, particularly for cochlear measurement and inner ear to provide road map to the cochlear implant surgeon, though both CT scan and MRI are complementary modalities to each other.

Thus, combined approach using specific HRCT and MRI section of inner ear in cochlear implant candidate will detect technical information like round window assess and patency of cochlear canal vary much needed by the operating surgeon.

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