The Egyptian Journal of Radiology and Nuclear Medicine 49 (2018) 652–657

Contents lists available at ScienceDirect

The Egyptian Journal of Radiology and Nuclear Medicine

journal homepage: www.elsevier.com/locate/ejrnm

Original Article

128-multidetector CT: For assessment of optimal depth of electrode array insertion in cochlear implant operations

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ARTICLE INFO

Keywords:
Multidetector CT (MDCT)
Cochlear implant (CI)
Cochlear length (CL)
Angle of insertion (α angle)

ABSTRACT

Objective: To assess the diagnostic reliability of MDCT in pre-operative evaluation of cochlear implant candidates and post-operative, estimation of depth of insertion.

Material and methods: The study includes 40 patients (18 males and 22, females); classified into 2 groups: group A (20 patients): cochlear, implant device was Nucleus-22. Group B (20 patients): device was MED-EL.

Cochlear length (CL) and cochlear height (CH) were measured pre-operatively by 128-multidetector CT. Electrode length (EL) and insertion, depth angle (α) were measured post-operatively by MDCT.

Results: Group A: mean CL was 9.1 mm ± 0.4 SD; mean CH was 4.1 ± 0.3 SD; mean EL was 18 ± 2.7 SD; mean α angle was 299.05 ± 37 SD. Significant, statistical correlation ($P < 0.05$) was found between pre-operative CL and, post-operative EL. Significant statistical correlation was found between, EL and α angle ($r2 = 0.7$). Group B: mean CL was 9.1 mm ± 0.3 SD; mean CH, was 4.1 ± 0.4 SD; mean EL was 27 ± 2.1 SD; mean α angle was 287.6 ± 41.7, SD. Significant statistical correlation was found between CL and EL & α angle.

Conclusion: Cochlear length is a reliable prognostic parameter in, prediction of the depth of electrode array insertion.

1. Introduction

Since the advent of the first cochlear implant (CI) in 1953 by Andre Djournoto, sensorineural hearing loss has been corrected in a vast number of patients all over the world [1]. This is owing to the progressing technical advances in cochlear implant devices which can stimulate the auditory cells in the spiral ganglion [2].

CI is designed with two devices linked together; the internal device is interfaced with the cochlear nerve, while the external device translates the acoustic stimuli into electric impulses [3]. Better results are achieved with electrodes in close proximity to the modiolus, to achieve the highest possible acoustic stimulation [4].

CT scan is the imaging modality of choice to obtain the detailed anatomy of the inner ear, which is a complex anatomical structure within the petrous part of temporal bone [5]. For instance, it can accurately delineate the anatomy of the basal turn of cochlea which is oriented as a three dimensional curve of “fish-hook” appearance. This is of particular importance regarding the proper surgical approach for cochleostomy at the site of the round widow (RW). Its variable anatomy makes it difficult for the surgeon to properly insert the electrode within the scala tympani without injuring the inner ear structures [6].

Moreover, preoperative multidetector CT (MDCT) with 3D reconstruction of volume rendered images has provided the surgeon with all required information about cochlear size, orientation and coiling pattern. The large variation in cochlear length, cochlear angle, and orientation in the skull base significantly affects the electrode insertion during the surgical procedure. Similarly, the size of the facial recess (space between the third portion of facial nerve and chorda tympani) influences electrode passage through the middle ear [7].

Postoperative CT is essential to confirm proper electrode array insertion and exclude post-operative complications. It is the modality of choice for the diagnosis and early management of electrode misplacement which is a major complication resulting in poor outcome [8].

Thus, the aim of this prospective research study was to assess the diagnostic reliability of MDCT in pre-operative evaluation of cochlear implant candidates for proper electrode device selection and post-operative estimation of the depth of insertion.

Peer review under responsibility of The Egyptian Society of Radiology and Nuclear Medicine.
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https://doi.org/10.1016/j.ejrnm.2018.05.001
Received 13 September 2017; Accepted 6 May 2018
Available online 03 July 2018

2. Material and methods

2.1. Patients

The study was conducted in the period between January 2014 and March 2016; for patients suffering from severe to profound bilateral sensorineural hearing loss (SNHL). Cases were referred from Otorhinolaryngology department to Radiodiagnosis department in order to perform pre and post-operative MDCT. Approval was granted from the University Institutional Review Board (IRB, code: MS/764).

Surgical planning was done after the analysis of radiological findings, audiologic and behavioral data. Forty patients underwent unilateral cochlear implantation (18 males and 22 females); mean age 5.6 years (age range between 3 and 18 years). Thirty seven patients (92.5%) presented with pre-lingual SNHL; while three patients (7.5%) presented with post-lingual SNHL.

The most common etiological factor was congenital SNHL (found in 34 patients, representing 85% of the total number of patients) and none of them showed syndromic manifestations; however, three of the patients (7.5%) had a positive family history. Other causes of SNHL, rather than congenital causes, were seen in three patients (7.5%) who had tympanogenic labyrinthitis ossificans.

Patients were classified into 2 groups according to the cochlear implant device: group A (20 patients): cochlear implant device was Nucleus-22. Group B (20 patients): device was MED-EL.

Methods: all cases underwent pre-and post-operative CT of both temporal bones (128-multidetector CT; Phillips Medical systems, Nederland). **Imaging parameters:** Images were obtained in 1 mm slice thickness, 0.5 s rotation time, 0.5–1 pitch factor, 140 KV tube voltage, 160 mA tube current, 200 mm scan field of view (FOV), 512 × 512 matrix, window level = 600 and window width = 4000. Images were reconstructed with slice thickness 0.6 mm. Scan volume extended from the jugular foramen to the superior margin of the petrous pyramid. Axial plane, parallel to the infraorbitomeatal line was the traditional slice orientation to display the petrous bone.

Image acquisition and post processing was conducted by the 4th author. Measurements were taken by the 3rd author (13 years of experience) under supervision of the 1st author (Professor in Radiology Dpt.)

Post processing: 2D reformatted images and 3D images were reconstructed as follows: 2D reformats in the coronal and sagittal planes. Multiplanar reformatted images (MPR) in a sagittal oblique plane, parallel to the long and short axes of cochlea for depiction of the anatomy of cochlear turns, cochlear aperture and modiolus. Sagittal oblique plane was constructed in the long axis of both round window and vestibular aqueduct. 3D reconstructions were made by using maximum intensity projection (MIP) for visualization of the cochlear turns.

Preoperative checklist included: full assessment of labyrinthine morphology and patency, modiolar deficiency, size of the endolymphatic duct and sac, orientation, size and number of cochlear turns and anatomy of the facial nerve canal.

Pre-operative measurements were performed as described in the literature; **cochlear length (CL)** was estimated by measuring the longest distance between the widest part of the lateral wall of the basal cochlear turn and the center of the round window (RW) (Fig. 1a). **Cochlear height (CH)** was obtained by measuring the distance between highest point of the apical turn and lower base of basal cochlear turn (Fig. 1b) [9].

2.2. Post-operative measurements

Electrode length (EL) and insertion depth angle (α) were measured post-operatively by MDCT. **Angle of insertion (α angle)** is the angle between the site of cochleostomy at the RW and the most apical electrode in the axial plane (Fig. 1c) [10].

3D reconstruction: was carried out to detect the spatial relation between the modiolous and the inserted electrode array and confirm successful insertion inside the Scala typani (Fig. 1d).

For MED-El device: it was possible to count the number of electrodes inside and outside the cochlea. The presence of 12 electrode contacts inside the cochlea signified full insertion (Fig. 1d); 10–11 electrode contacts indicate partial insertion and 7–9 contacts indicate incomplete insertion.

This was not possible, with Nucleus-22 device because individual electrodes could not be discerned. So, we localized the most apical electrode subjectively according to its anatomical orientation in the standardized cochlear quadrants described by Colby et al., 2014 [11] (Fig. 2). Two cases with congenital anomalies were excluded because the quadrant nomenclature is not applicable in cases with severe malformation.

2.3. Statistical methods

Collected data were analyzed using SPSS program (Statistical Package for Social Sciences) software version 20. Descriptive statistics were displayed as mean, standard deviation, minimum and maximum range; for numerical data. Categorical data were described by number and percentage. Analyses were done for parametric quantitative variables using one way ANOVA. Chi square test was used for qualitative data between groups. Correlation between two quantitative variables was done by using Pearson's correlation coefficient; while correlation between ordinal variables was done by using non-parametric Spearman's rho correlation coefficient. The level of significance was considered at (P value ≤0.05).

3. Results

Results of preoperative assessment by MDCT are summarized in Table 1. Preoperative measurements: mean CL was 9.1 mm ± 0.4 SD and mean CH was 4.1 ± 0.3 SD for group A (Nucleus-22 implant device). Mean CL was 9.1 mm ± 0.3 SD and mean CH was 4.1 ± 0.4 SD for group B (MED-EL device). It was not possible to obtain these measurements in two cases with congenital anomalies (bilateral incomplete partition type I and common cavity), so both were excluded from the statistical analysis.

3.1. Postoperative assessment

Group A: the quadrant in which the inserted electrode array was located was demonstrated by post-operative MDCT (Fig. 2). Electrode array was inserted in the basal and middle turns, corresponding to quadrants IV to VI; except for one case where the array was advanced to quadrant X and another case where the array was seen in quadrant III (incomplete insertion) (Table 2).

Mean EL was 18 ± 2.7 SD; mean α angle was 299.05 ± 37 SD (Table 3). Significant statistical correlation ($P < 0.05$) was found between preoperative CL and post-operative EL ($r^2 = 0.6$), but not with α angle. Significant statistical correlation was found between EL and α angle ($r^2 = 0.7$). As for preoperative CH, it did not correlate with any of the post-operative measurements (Table 4).

3.2. Group B

Complete insertion of the electrode array was achieved in all cases with the exception of one case, only 4 electrode contacts were seen inside the cochlea. Incomplete insertion was reported and it was excluded from statistical analysis.

Mean EL was 27 ± 2.1 SD; mean α angle was 287.6 ± 41.7 SD (Table 3). Significant statistical correlation was found between CL and EL (r2 = 0.5) & CL and α angle (r2 = 0.6). Also a strong correlation was found between EL and α angle (r2 = 0.8). Preoperative CH correlated