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OTOLOGY

Which imaging modality in cochlear implant candidates?

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Abstract

Purpose There is no guideline or consensus on preoperative radiologic imaging modality despite the fact that it has a vital importance in appropriate candidacy selection of cochlear implantation. We aimed to find out the role of high-resolution computed tomography (HRCT) and magnetic resonance imaging (MRI) on surgical planning, intraoperative technique in cochlear implant candidates.

Methods The clinical charts, imagings, and operative reports of patients who underwent cochlear implant surgery at a tertiary institution were retrospectively examined.

Results 611 patients (503 children and 108 adult) were enrolled into the study. We found 11 different pathologies in MRI which could not be seen in HRCT. However, we decided the side of surgery according to MRI in only three of them in which the pathology was cochlear nerve hypoplasia. Two patients with cochlear nerve hypoplasia were children with prelingual deafness and one was adult with perilingual deafness. Moreover, we changed the surgical planning of side according to both imaging modalities in nine patients. Seven of them were children and two were adult. One of these adults had cochlear anomaly, and another had bilateral temporal bone fracture.

Conclusions We suggest both imaging modalities in pediatric candidates. However, in adults, we think that superiority of either imaging modalities is still contradictive. We had only three adult patients and the decision of the side of surgery was made according to MRI in one of them and to both imaging modalities in the other two adults.

Keywords Cochlear implantation · Imaging · Candidate

Introduction

The number of centers performing cochlear implantation (CI) has increased in recent years and appropriate candidacy evaluation is critical for successful operation. Radiographic assessment is important during work-up of patient selection.

High-resolution computed tomography (HRCT) or magnetic resonance imaging (MRI) or both can be used and choice of imaging modality can be altered based on institutional protocols and surgeon preference. The main purpose of standard preoperative radiographic evaluation is to identify congenital abnormalities and temporal bone pathologies that may alter surgical technique or contraindicate surgery and preclude successful implantation [1, 2].

The estimated rate of cochleovestibular anomalies in pediatric candidates is up to 35% [3]. Furthermore, surgical planning can be affected due to anatomic abnormalities in up to 20% of pediatric cases [4]. Therefore, preoperative imaging is recommended in pediatric candidates but there is no consensus on choice of imaging modality. MRI can

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identify cochlear or semicircular canal dysplasia, labyrinth ossification and the caliber of cochlear nerve. HRCT can identify bony labyrinth anomalies such as enlarged vestibular aqueduct, narrowing of cochlear nerve canal, etc., and can evaluate the variations of anatomic landmarks that may complicate the surgery or patient management during follow-up period such as aeration of the temporal bone, course of the facial nerve, position of the sigmoid sinus or jugular bulb or dura or lateral semicircular canal, carotid artery dehiscence, and the round window patency which is important, especially in patients with otosclerosis and meningitis. Therefore, the major superiority of MRI is better soft tissue visualization, to identify early ossification of the labyrinth which is important, especially in patients with meningitis, and the presence or absence of the cochlear nerve. However, it requires sedation in pediatric patients. On the other hand, the major superiorities of HRCT is to identify better visualization of bony labyrinth anomalies, caliber of the cochlear nerve canal, anatomic variations which are very important guidelines during surgery to provide further assistance in orienting the surgeon and also, it does not require sedation because of the short duration of process. Although the amount of radiation should be considered, it has several advantages. Moreover, it is more conflicting in adults, especially in the postlingually deafened ones. Although there is numerous reports regarding the utility of preoperative imaging in postlingually deafened adults, they have conflicting results [4–7]. Roberts et al. did not suggest routine preoperative imaging in adult patients without a concerning clinical history [5]. Choi et al. detected low ratio of anatomic abnormalities which may affect the surgical course in these patients [8]. On the other hand, MRI was recommended for preoperative evaluation in the study of Sweeney et al. [9]. The ratio of anatomic abnormalities can be altered according to the racial and ethnical differences and this may be the reason of conflicting results of previous studies [4–9].

Although preoperative radiographic evaluation can be useful in surgical planning, there is no guideline or consensus on preoperative radiologic evaluation. To date, both HRCT and MRI have been part of preoperative work-up in our clinic. We reviewed our database to evaluate preoperative radiological signs and surgical findings of CI patients in our department. In the present study, we aimed to answer the questions given below.

Which one of the imaging modality should we prefer to assess CI candidates? Is only HRCT or MRI enough or both required?
What is the superiority of either of these?
What is the role of these imaging modalities on surgical planning and intraoperative technique?

Materials and methods

We performed a retrospective observational study in cochlear implantees which was approved by the local ethics committee. The clinical charts, imagings, and operative reports of patients with bilateral profound sensorineural hearing loss (SNHL) underwent cochlear implant surgery at a single tertiary institution between 2008 and 2018 were retrospectively examined. Of these, patients with lack of available database from medical records for review were eliminated from the study. Demographic data including period of hearing loss, age at implantation, and gender were recorded. The side of surgery, surgical findings and the radiologist's report of HRCT and MRI, and the pathologies that cause any alteration of surgical technique were noted. We request both HRCT of temporal bone and MRI of internal acoustic meatus routinely in all cases as the standard imaging modality at our clinic. Reports were reviewed by the same author for each patient in the study. The imaging findings were compared with both decision of side of implantation and findings at surgery. We divided patients into three subgroups as pre-lingual, peri-lingual and post-lingual according to the onset of hearing loss.

Results

Chart review resulted in 634 cochlear implants performed between 2008 and 2018. Of these, 23 implants did not have radiologic data available for review, complete clinical charts or operative notes and were excluded. Afterwards, 611 implants (283 women and 328 men) met inclusion criteria. All patients presented with symmetrical bilateral profound SNHL and received both HRCT and MRI.

The age range was from 1 to 75 in this study. Five hundred three pediatric (younger than 18 years of age) and 108 adult (older than 18 years of age) patients underwent cochlear implantation successfully. We decided the indication of implant according to only MRI in 2 of 503 pediatric patients who had cochlear nerve hypoplasia. However, we got benefit to perform the CT scan in all these patients because they had also cochlear anomalies and anatomic variations and CT scan provided further assistance in orienting our decision about surgical planning.

The 454 patients had prelingual, 74 had perilingual, 83 had postlingual deafness. The average age was 3.94 years in prelingually deaf group, 11 years in perilingually deaf group and 42.7 in postlingually deaf group. We had four adult patients with chronic otitis media (COM) who had previous mastoidectomy, whereas we did not detect vestibulocochlear labyrinth destruction in none of these in both

imaging modalities. Moreover, we had ten patients with otosclerosis and there was ossification in round window in three of these but implant insertion was successful.

We found 11 different pathologies in MRI which could not be seen in HRCT, whereas eight of these pathologies did not change the indication, approach or side of the surgery. These pathologies were arachnoid cyst, ependymoma in lateral ventricle, leukodystrophia, vascular loop and widened endolymphatic sac. However, there were three patients with cochlear nerve hypoplasia. Two patients were children with prelingual deafness and one of these had also aural atresia and the other one had also cochlear hypoplasia. One patient was adult with perilingual deafness and had no vestibulocochlear labyrinth anomaly. We decided the side of surgery according to MRI in all the patients with cochlear nerve hypoplasia.

We decided the side of surgery according to both imaging modality in nine patients. We changed the surgical planning of side because of cochlear anomaly in six children and because of narrow internal acoustic meatus in one child. Although all of these findings are present on MRI, we got the benefit to perform CT scan in all these patients because they had also anatomic variations such as extremely anteriorly located sigmoid sinus, high jugular bulb which prevents visualization of round window, etc., and CT scan provided further assistance in orienting our decision about surgical planning. We changed the surgical planning of side because of cochlear anomaly in one adult and because of bilateral temporal bone fracture in another one.

We observed anatomic variations in 91 (14.9%) of all patients in the CT scan, whereas in only 9 (1.4%) in the MRI. Temporal bone HRCT identified enlarged vestibular aqueduct in 32 (5.2%) patients, whereas MRI identified in 15 (2.4%) patients.

The findings of HRCT of temporal bone is noted in Table 1 and the findings of MRI of internal acoustic meatus is noted in Table 2.

Discussion

We evaluated the utility of imaging in selection of cochlear implant candidates as retrospectively examining clinical charts of the 611 cochlear implant patients. We changed our decision about the surgical course according to preoperative imaging modalities in 12 patients which were mostly children. Based upon our results, we suggest both imaging modalities in pediatric candidates. However, in adults, we think that superiority of either imaging modalities is still contradictive.

The candidacy evaluation for CI should comprise a series of tests including detailed otolaryngological examination, audiologic and hearing aid evaluation, radiographic assessment, speech and language evaluation, and patient/family counseling [10–12]. The purpose of standard preoperative radiographic evaluation is to define the etiology of SNHL such as congenital abnormalities of the middle and inner ear, infections, etc., choose the side which may be the most appropriate for CI, locate the positions of surgical landmarks to predict possible complications and identify temporal bone pathologies that may alter surgical technique or contraindicate surgery and preclude successful implantation.

Table 1 The findings of high-resolution temporal bone computed tomography (others: mastoiditis, ossicular problems, soft tissue in middle ear, etc.) (lesions on dura mater: low lying dura, erosion of dura, etc.)

Lesion	Prelingual	Perilingual	Postlingual	Total
Anatomic variations (facial nerve, jugular bulb, dura, etc.)	62 (13.6%)	11 (14.8%)	18 (21.6%)	91 (14.9%)
Enlarged vestibular aqueduct	20 (4.4%)	11 (14.8%)	1 (1.2%)	32 (5.2%)
Cochlear anomaly	26 (5.7%)	10 (13.5%)	4 (4.8%)	40 (6.5%)
Otosclerotic foci			10 (12%)	10 (1.6%)
Semicircular canal anomalies	4 (0.8%)		1 (1.2%)	5 (0.8%)
Temporal fracture			1 (1.2%)	1 (0.2%)
Others	7 (1.5%)	2 (2.7%)	15 (18.07%)	24 (3.9%)

Table 2 The findings of magnetic resonance imaging of internal acoustic meatus (others: arachnoid cyst, ependymoma in lateral ventricle, leukodystrophia, vascular loop and widened endolymphatic sac etc.) (lesions on dura mater: low lying dura, erosion of dura, etc.)

Lesion	Prelingual	Perilingual	Postlingual	Total
Cochlear anomaly	30 (6.6%)	4 (5.4%)	2 (2.4%)	36 (5.8%)
Semicircular canal anomalies	4 (0.8%)			4 (0.6%)
Enlarged vestibular aqueduct	11 (2.4%)	4 (5.4%)		15 (2.4%)
Anatomic variations (facial nerve, jugular bulb, dura, etc.)	6 (1.3%)	2 (2.7%)	1 (1.2%)	9 (1.4%)
Others	8 (1.7%)	2 (2.7%)	4 (4.8%)	14 (2.3%)

Above all, determining the extent of cochlear patency and the presence of cochlear nerve are critical. The presence of any deformities can also alter electrode array choice [1, 2].

We use both HRCT and MRI in the preoperative work-up in our clinic. However, the protocol remains variable all around the world and the reports on the possible superiority of either HRCT or MRI in preoperative evaluation is still conflicting [1, 13, 14]. The caliber of the cochlear nerve canal can be best seen in HRCT, whereas presence or absence of the cochlear nerve can be best seen in MRI [15, 16]. Additionally, although MRI has the advantage of no radiation exposure, there is a cost difference in comparison to HRCT.

Otosclerosis and COM are two surgical challenges in especially adult patients. Previous studies have reported that the possibility of complications such as meningitis or implant extrusion increases in COM patients [5]. Roberts et al. evaluated the preoperative imaging findings of adult candidates and they reported that although they did not identify any patients with COM, 14.4% of the patients had radiographic evidence of COM. On the other hand, we had four patients with COM who had previous mastoidectomy. We mainly decided the side of implant according to physical exam findings. None of our patients had extrusion of their device or meningitis. In spite of our results, we suggest preoperative temporal bone HRCT in patients with COM because anatomical landmarks can be changed according to the disease course and/or previous mastoidectomy which can also alter surgical technique. Otosclerosis can also alter the CI surgical course. Because, ossification of the round window and/or scala tympani, which can be present in otosclerosis, is important for successful implant placement. The sensitivity of HRCT imaging in detecting otosclerosis was reported as between 71 and 78% [17]. In a report of nine otosclerosis patients, HRCT showed ossification of the round window in four patients, whereas eight patients had ossification of the round window intraoperatively. Nevertheless, an implant was placed without difficulty in all patients [18]. In another study, concerning the preoperative imaging findings of adult candidates, preoperative imaging was suggested in regard of the potential of ossification in otosclerosis patients [5]. In the present study, we had ten patients with otosclerosis, whereas we had only three patients with the ossification of the round window which was detected in temporal bone HRCT and confirmed by clinician during surgery. Although we performed implantation without difficulty in all cases, we think that preoperative temporal bone HRCT in patients with otosclerosis is conceivable. Because, we had a few patients with surgical challenges such as otosclerosis, COM, etc., and we did not have any extremely difficult case which can alter the implant decision.

Another dilemma in adult candidates is the role of imaging modalities on surgical planning in patients without the history of COM, otosclerosis, trauma, etc. Although the cochleovestibular anomalies is estimated as the rate of up to 35% in pediatric candidates [3], it is extremely rare in postlingually deafened adult patients. Because of this concern, Roberts et al. did not suggest routine preoperative imaging in adult patients without a concerning clinical history [5]. Choi et al. determined that adult patients without the history of middle or inner ear diseases, autoimmune diseases, trauma or neoplasms may not require preoperative assessment because of the low ratio of anatomic abnormalities which may affect the surgical course [8]. Consistent with these studies, we changed the surgical planning of side in only three adults. One postlingually deafened adult had history of head trauma and bilateral temporal bone fracture and we decided the side of surgery according to both imaging modalities and audiologic test results. The second adult had unilateral Mondini and contralateral Michel deformity and the onset of hearing loss was peri-lingual period. The third perilingually deafened adult had cochlear nerve anomaly without vestibulocochlear labyrinth anomaly. However, we had no postlingually deafened adult patient with a finding that implant is contraindicated. Additionally, we had 4 (4.8%) postnatally deafened patients with cochlear anomaly, but, none of these changed our surgical planning.

There is no consensus on choice of imaging modality in also pediatric candidates. HRCT is beneficial in identifying the cochleovestibular anomalies [3]. Besides that, McClay et al. detected 18% cochlear nerve absence or deficiency which could be mostly identified by MRI of internal auditory canal [19]. Tahir et al. detected that MRI can show aplastic or hypoplastic nerve even if the cochlear structure is normal and they suggested both HRCT and MRI to evaluate cochlear nerve patency [20]. We changed the surgical planning of side in pediatric candidates because of cochleovestibular anomaly in six children, narrow internal acoustic meatus in one child and cochlear nerve hypoplasia in two children. Although all of these findings are present on MRI, we got the benefit to perform CT scan in all these patients because they had also anatomic variations such as extremely anteriorly located sigmoid sinus, high jugular bulb which prevents visualization of round window, etc., and CT scan provided further assistance in orienting our decision about surgical planning. Additionally, we observed anatomic variations in 91 (14.9%) of all patients in the CT scan, whereas in 9 (1.4%) in the MRI and temporal bone HRCT identified enlarged vestibular aqueduct in 32 (5.2%) patients, whereas MRI identified in 15 (2.4%) patients. Although these findings did not change the indication of implantation, these additional information are important landmarks to provide guidelines to the surgeon. For instance, there is increased risk of cerebrospinal fluid gusher in patients with enlarged vestibular aqueduct, any variation of facial

nerve trunk or extremely anterior location of the sigmoid sinus may preclude the traditional facial recess approach, and the high location of jugular bulbs overlying the round window niche may complicate surgery. Therefore, we suggest both imaging modality in pediatric candidates based on the study of Tahir et al. and our findings.

The major limitation of our study is that we only evaluated the patients who had CI surgery but we did not evaluate the patients who we declined to perform CI in our implantation council. We did not include these patients to avoid bias, because, we did not have complete clinical charts of all patients. We had 4 (4.8%) postnatally deafened patients with cochlear anomaly and none of these changed our surgical planning. However, if we could have added the refused patients in implantation council, this rate might be changed. Moreover, we had no imaging findings which are the contraindications of CI such as bilateral Michel deformity, bilateral cochlear nerve absence, etc. On the other hand, we had conflicting results in adult patients. Therefore, future studies including also patients with severe to profound SNHL without CI should be performed.

Conclusion

MRI can show aplastic or hypoplastic nerve even if the cochlear structure is normal, whereas CT scan can provide better visualization of cochlear structure anomalies, evaluate the round window patency, variations of anatomic landmarks. We suggest both imaging modalities in all pediatric candidates. Because, although we changed the surgical planning of side in pediatric candidates mostly in regard of the findings of MRI, we changed our surgical planning according to their anatomic variations which were identified in temporal bone HRCT. Besides that, the amount of radiation of CT scan should be considered. However, in adults, we think that superiority of either imaging modalities is still contradictive. Because we had only three adult patients and the decision of the side of surgery was made according to MRI in one of them and to both imaging modalities in the other two adults.

Compliance with ethical standards

Conflict of interest None of the authors has any financial or other relationship that might lead to conflict of interests.

Ethical approval All procedures performed in this study involving human participants were in accordance with the ethical standards of institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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