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Role of Multislice Computed Tomography with 3D Imaging in Diagnosis of Temporal Bone Lesions

Dr. Wael Hamza Kamr[a], Dr. Amir Monier Eltantawy[a], Dr. Wesam Monir El-Tantawy[b]

[a]Diagnostic Radiology, Mansoura University, Egypt
[b]Diagnostic Radiology department, Banha University
dr.waelkamr@gmail.com

Abstract

Introduction: MSCT is presently the most accurate technique to study the temporal bone anatomy or pathology.

Objective: To evaluate the utility of MSCT imaging with 3D reconstruction in assessment of temporal bone lesions

Patients & Methods: This study included 100 patients (46 males & 54 females) their age ranged from 1:73 years. They had variable problems; hearing loss, vertigo, tinnitus, suspected otitis media, congenital malformation, trauma, inflammatory or neoplastic lesions. MSCT with 3D reconstruction was done for all patients. 3D reconstruction done using MIP & VR techniques.

Results: Our study included 11 patients with external ear pathology (5 patients with otitis externa, 4 patients with osteochondroma & 2 patients with external ear deformity). 40 patients with middle ear pathology (25 with otitis media & 15 with cholesteatoma), inner ear pathology in 5 patients (2 congenital, 3 post cochlear implant) and 18 patients had other variable pathology; 8 patients with trauma however only 4 patients had fractures, 2 patients with jugular dehiscence, 2 patients with jugular bulb ectasia, 1patient with petrous apex cyst, 2 patients with mastoid fibrous dysplasia, 2 patients with Dermoid cyst and the last patient with meningioma enplaque showing squamous bone thickening.

Conclusion: MSCT 3D reconstructed images played an important role in assessment of the anatomical details of small middle ear and inner ear structures pathological changes; however it needs much familiarity with the 2D anatomy and caution in post processing to avoid false results and artifacts. Further studies for specific pathology will be more beneficial than evaluation of variant pathology.

Keywords: Multi-slice CT (MSCT), 3D, temporal bone.

Introduction

The temporal bone is a complex structure with five developmentally different regions and multiple variable pathological lesions. Multislice computed tomography (MSCT) is presently the most accurate technique to study the temporal bone anatomy or pathology as it offers excellent delineation of the ear. It can show bony walls of the external and middle ear, the bony labyrinth, the bony facial nerve canal, the bony internal auditory canal.[1]

Recent developments in CT software technology have made it possible to rapidly generate the three-dimensional (3D) and multiplanar reformatted (MPR) images from conventional (2D) cross-sectional computed tomographic (CT) data.[2] The additional information provided by 3D reconstructed images allows a better understanding of temporal bone complex anatomy containing multiple small structures and improves the ability to evaluate related disease, in addition it helps much to optimize adequate surgical planning.[3]

The aim of this study directed to: Evaluate the utility of Multislice CT imaging with 3D reconstruction in assessment of various temporal bone lesions

Patients and Methods

Patient Selection

Our prospective study included 100 patients (46 males and 54 females), their age ranges from 1 to 73 years who had temporal bone problems like hearing loss, vertigo, tinnitus, suspected otitis media, congenital malformation, post traumatic fracture, inflammatory or neoplastic lesions. The study was done at security forces hospital, Makkah, where the patients were referred from ENT clinics to the radiology department, from January 2015 till December 2016, with no age or sex predilection. The study was approved from the ethical committee and a written consent was taken from each patient included in the study. MSCT examination carried in using SOMATOM Definition AS (64 detector) Multislice CT machine, Siemens/Germany (2012). All patients were subjected to history taking and full clinical examination. MSCT scan with 3D reconstruction images were done for all patients. 3D reconstruction was done using MIP and VR techniques

MSCT Technique

Patient Preparation

Examination procedure explained to the patient or to the relatives of the young patient or child in order to obtain his/her cooperation. Removal of any metallic objects at head and neck to avoid image artifact. Patient placed in a symmetrical supine position (head first using head rest), with flexion or extension of the neck to limit irradiation of the lens to a minimum.

Image Acquisition and Scanning Parameters

The studies were performed with the following parameters: 0.75 mm collimation, 1mm section thickness, 120 kVp, 240 mAs, pitch of 0.6, rotation time 0.75 sec, 15 cm field of view, filter bone, and a 512 x 512 matrix. The initial data sets were then reconstructed at 0.6 mm slice thickness. The axial scan was done with the patient in supine position and the gantry tilted 0 while the scanning plan was parallel to the orbito-meatal line. Images were started inferiorly below the lower margin of external auditory meatus. Nonionic water soluble contrast media (Visipaque 320 mgI/ml) was used in 5 patients with suspected soft tissue lesions and intra-cranial extension.

Image Processing and Reconstruction

In our study, post processing and reconstructions methods included 2D MPR for routine reconstruction while MIP and VR techniques were used for 3D reconstruction.

Multiplanar Image Reconstruction (MPR)

Had done in 3 different planes, axial, coronal and sagittal planes. Axial images reconstructed parallel to the lateral semicircular canal. Coronal plane images perpendicular on TMJ while sagittal images done with the longitudinal axis parallel to the longitudinal petrous axis giving sagittal oblique images that clarify the small tiny structure of the middle and inner ear.

Three-Dimensional (3D) Image Reconstruction

By using maximum intensity projection (MIP) and volume rendering (VR) methods we were able to create 3D images especially of the small structure of the middle and inner ear.

Maximum Intensity Projection (MIP)

This technique displays the pixels of greatest intensity along a predefined axis of the image. During the processing of the image data there were two types of MIP, the ordinary MIP and thin MIP.

Ordinary (Thick) MIP, by selecting thick MIP the details of the small structure like ossicels and inner ear structure is not clear, however by selecting **Thin MIP**, utilization of the images related to area of interest results in delineation of small structures and their details. Also we can separate small structure like ossicels or cochlea from the other bones by cutting and removing the surrounding bones guided by other 2D MPR images.

Volume Rendering (VR)

The technique interpolates the entire data set rather than editing a single scan to generate 3D images directly from scanned volume data. In our study concerning the temporal bone, we have chosen the musculoskeletal bone window. After zooming and removing other parts of the skull bones, we achieved selected 3D images of the temporal bone specially its petrous part, however the details of the small structures were unclear.

Thin Volume Rendering (VR)

Method provided us with 3D volumetric image. The images were so demonstrative and the anatomic details of small structures were clear. Also using the different window options of VR, we found that the transparent window is very good in delineation of the middle ear ossicels and inner ear structures.

Result

This study included 100 patientshad problems related to the temporal bone like hearingloss, vertigo, tinnitus, suspected otitis media, congenital malformation, post traumatic fracture, inflammatory or neoplastic lesions. They were 46 male and 54 female with age range from 1 to 73 years (mean age about 47). Although there was a wide range of age, it has no significance as the study was not directed to a specific temporal bone pathology or sex or age predilection.

In our study; the most common symptom was hearing loss followed by discharge and tinnitus (table1). However, there were two patients with different complaint not related to the temporal bone; one had proptosis and diminution of vision and the other had epilepsy. Both patients after doing CT we found pathology related to the temporal bone (meningioma en-plaque and petrous apex cyst consequently)

The commonest provisional clinical diagnosis of the patients was the hearing loss (31 patients had SNHL and 30 patients had CHL) followed by otitis media and the least diagnosis was external ear deformity in two patients (table 1). MSCT had been done for all patients included with the findings broadly classified according to the region of the pathology that correlated to the clinical symptoms in almost of the cases (table 2).

Regarding the MSCT findings, external ear pathology detected in 11 patients (11%), middle ear pathology in 40 patients (40%), 31 patients (31%), with inner ear symptoms but positive findings only in 5 patients (5%) and 18 patients (18%) with variable pathological lesions. On the other hand, 31 patients (31%) had normal CT findings although they had symptoms related to temporal bone, 26 had SNHL and the remaining 4 patients had history of trauma related to temporal bone however no fracture was detected.

For the external ear, there were 5 patients (5 out of 11 patients, 45.4%) with otitis externa, 4 patients (4 out of 11 patients, 36.4%) with osteochondroma and 2 patients (2 out of 11 patients, 18.2%) with external ear deformity that being atresia of the external auditory canal and small accessory auricle with normal external auditory canal. (Table 2) In cases of middle ear pathology were 25 (25 out of 40 patients, 62.5%) with otitis media and 15 (15out of 40 patients, 37.5%) with cholesteatoma. For the inner ear although there were 31 patients (31%) suffering from SNH loss only 5 patients (5 out of 31 patients, 16.13%) showed findings in MSCT, 3 post cochlear implant and 2 congenital (one case is Mondini malformation and the other one is common cavity). Other pathological varieties were detected in 18 patients (18%), 8 patients with trauma however only 4 patients had fractures, 2 patients with jugular dehiscence, 2 patients with jugular bulb ectasia, 1 patient with petrous apex cyst, 2 patients with mastoid fibrous dysplasia, 2 patients with Dermoid cyst and the last patient with meningioma enplaque.

Table1. *Showing the clinical presentations, examination and provisional diagnosis of 100 patients with temporal bone diseases*

Clinical presentation (Symptoms)*	Clinical examination (Signs)*	Region of the pathology	Provisional diagnosis
Diminished hearing (61)	Otorrhea (40)	External ear (11)	5 otitis externa 4 EAC mass 2 congenital deformity
Aural pain (15)	Drum perforation (15)	Middle ear (40)	Inflammatory CSOM30versuscholesteatoma 10
Tinnitus (24)	Conductivehearing loss (30)	Inner ear (31)	SNHL 3 post cochlear implant
Aural discharge (40)	Sensory hearing loss (31)	Trauma (8)	Fracture
Fever (8)	External ear mass (4)	Mastoid bony swelling (2)	Bony lesions
Vertigo and dizziness (10)	Cholesteatoma (10)	Subcutaneous peri-auricular soft tissue mass (2)	Dermoid cyst / LN
Headache (16)	Otitis media (30)	Swelling of the squamous temporal bone (1)	Bony lesion
Swelling (10)	Otitis externa (4)	Jugular fossa (4)	Pulsatile tinnitus
Trauma (8)	Mastoid swelling (2)	Petrous apex (1) (retrograde after CT)	
Auricle deformity (2)	Subcutaneous swelling (2)		
Proptosis (1)	Trauma of temporal bone (8)		
Epilepsy (1)	External ear deformity (2)		
Follow up after cochlear implant (3)			

* Many patients had more than one symptoms and signs

Table2. *Showing the MSCT & 3D evaluation and diagnosis of 100 patients with temporal bone disease*

Region	***MSCT & 3D findings***	***No***	***Diagnosis***	
External ear	Diffuse soft tissue density filling the EAC	5	Otitis externa	
	Small hyperdense bony outgrowth	4	Osteochondroma	
	Small sized deformed auricle, absent and EAM & EAC	1	Artesia of external auditory canal	
	Small sized accessory auricle, normal EAM & EAC	1	Small accessory auricle with normal external auditory canal	
Middle ear	***MSCT & 3D findings***	***No***	***Diagnosis***	
			CSOM(25)	***Cholesteatoma(15)***
	Thickening of T.M.	25	20	5
	Fluid density in middle ear	20	20	0
	Soft tissue density	20	5	15
	Bone destruction	15	0	15
	Ossicular erosion	15	2	13
	Intracranial extension	2	0	2
	Fluid density in mastoid air cells	20	15	5
	Mastoid sclerosis	14	5	9
	Mastoid destruction	6	0	6
Inner ear	***MSCT & 3D findings***	***No***	***Diagnosis***	
	Cystic cochleovestibular malformation with cystic vestibule present but separated from cochlea	1	(Type I IP) Mondini malformation	
	Communication of the cochlea and vestibule with no differentiation	1	Common cavity Deformity	
	Adequate position of the implant electrode	3	Post CI	
	No abnormality detected	26	Normal	
Other variable regional pathology	***MSCT & 3D findings***	***No***	***Diagnosis***	
	Well defined Subcutaneous soft tissue masses with fat density	2	Dermoid cyst	
	Diffuse sclerosis and enlargement of the mastoid bones with no destruction	2	Mastoid Fibrous dysplasia	
	Fractures involving the squamous and petrous parts of temporal bone	4	Post traumatic fracture	
	Trauma with no fracture detected	4	No fracture	
	Thickening and sclerosis of the greater wing of the sphenoid and squamous parts of the temporal bone associated with small enhanced meningioma	1	Meningioma en-plaque	
	Absent bony wall separating the jugular vein from the middle ear cavity	2	Jugular bulb dehiscence	
	Dilated jugular fossa and bulb with intact bony wall. No masses	2	Jugular bulb ectasia	
	Petrous apex a well-defined expansile cyst seen at the petrous apex. Thinning cortex. No destruction. No masses. No enhancement	1	Cephalocele cyst	

Discusion

As regard the external ear**, Dubach and Häusler**[4] statedthat simple otitis externa is a common disease of the external auditory canal and characterized by diffuse thickening and edema of its wall. The previous mentioned findings matches with our current study as 11% of the patients included had external ear pathology, 45.45% of them had simple otitis externa with the most common findings was diffuse thickening and edema of mucosal lining of the external auditory canal however no evidence of extension to TMJ or associated bone erosion or destruction as a differentiating point for external ear cholesteatoma**.**

In agreement with **Pasetto et al.,**[1], actually CT findings gained from the axial images and MPR was enough for the diagnosis. On these cases, 3D reconstructed images excluded pathological changes of middle and inner ear and provided us a good delineation of their anatomical details.

Case 1

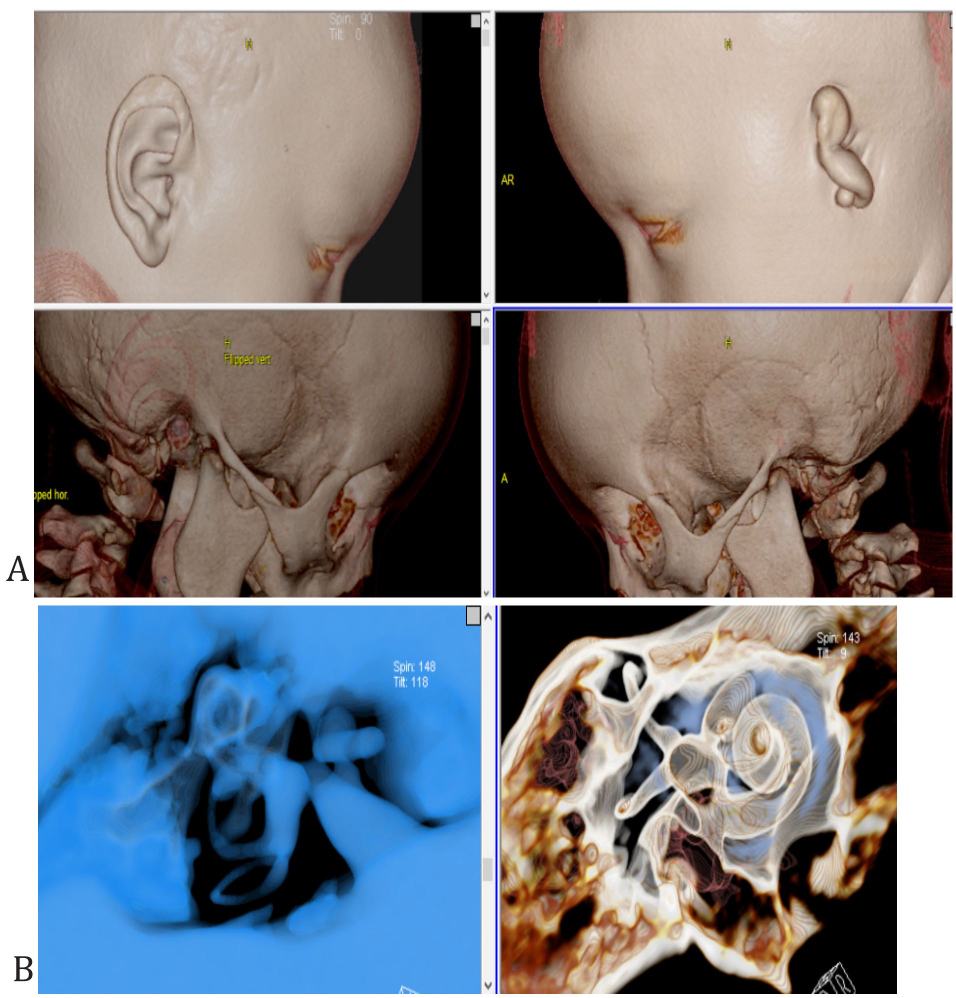
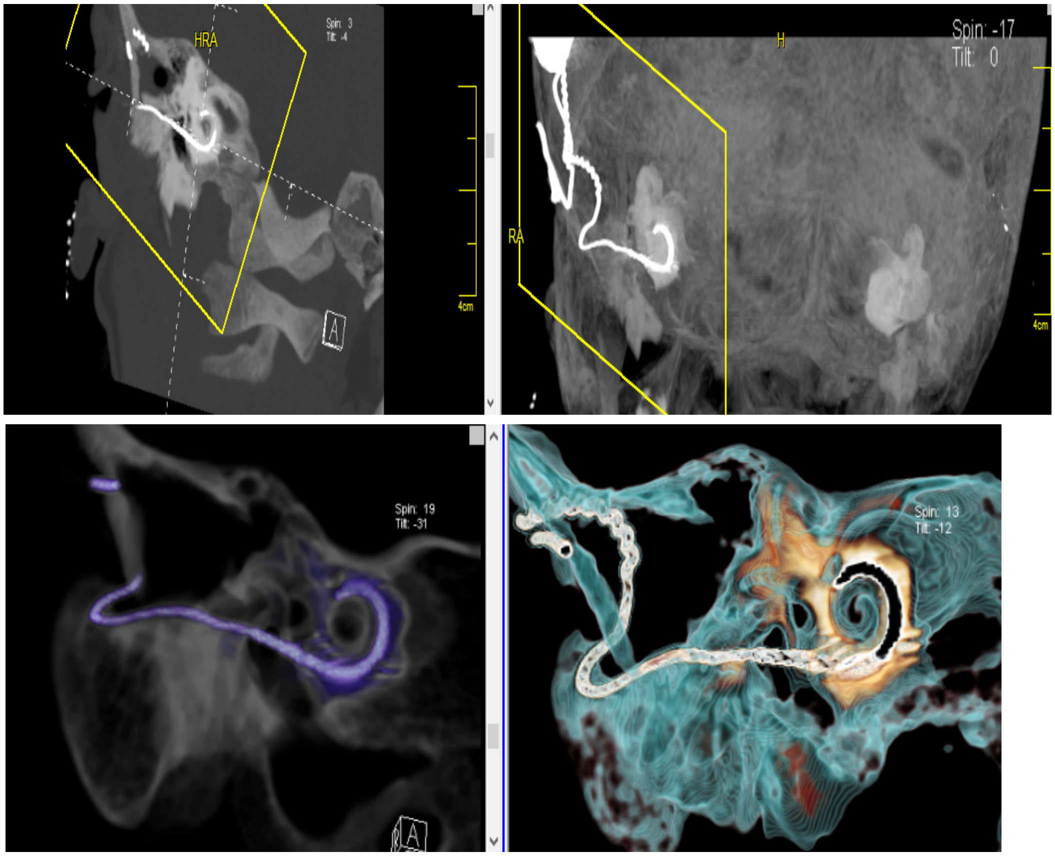


Fig1. Left external auditory canal atresia: *A): 3D Thick volume rending images (bone & soft tissue window) showing absent external auditory opening and small deformed auricle on the left side with normal appearance on the right side. B):3D Thin volume rending images of (the inner ear) showing normal cochlea and semicircular canals*

Case 2

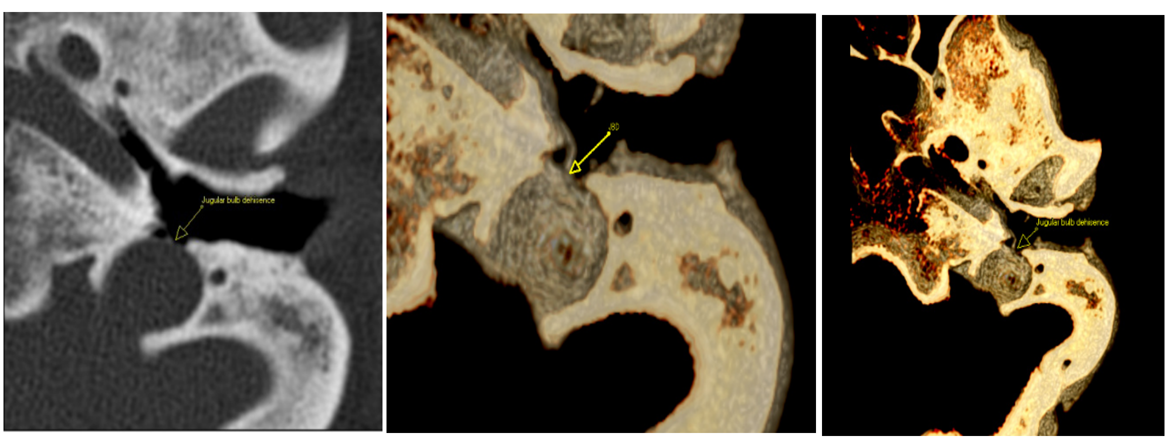


A

B

Fig2. Well positioned Cochlear implant: *(A) Thin MIP 3D images. (B) Thin 3D VR images Showingwell positioned cochlear implant with smooth curve within the cochlear turns with no kink or overlapping,*

Case 3



A. B. C.

Fig3. Jugular Bulb Dehesince *A): axial images, (B,C):Thin VR 3D images showing the bone defect at the lateral wall of the jugular fossa*

Case 4

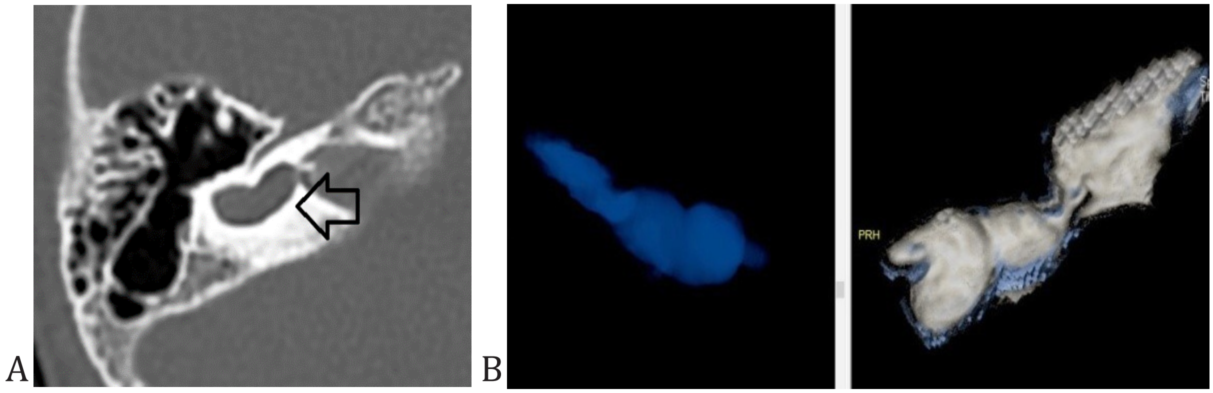


Fig4. Common cavity: *A) Axial 2D images showing the abnormal widening of both cochlea and vestibule forming large common cystic structure. B) Thin VR images of the inner ear showing widening and abnormal configuration of the cochlea and vestibule*

Case 5

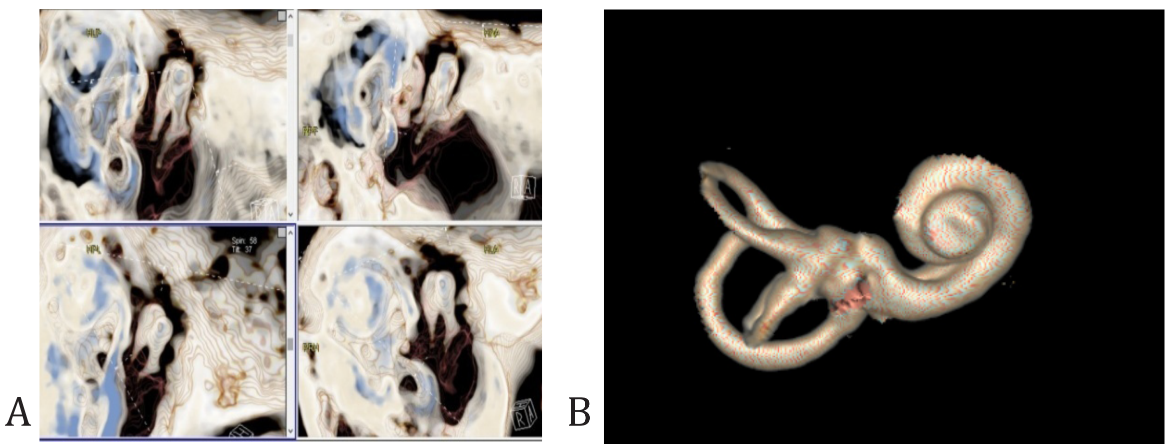


Fig5. Case of sensory neural hearing loss: *A) Thin VR images showing normal middle ear ossicles. B) Thin VR images of the inner ear showing normal appearance of the cochlea and semicircular canals.*

On the other hand, **Trojanowska et al.,**[5] **and Juliano et al.,**[6] reported thatosteochondroma founded at the external ear as a small hyperdense bony outgrowth was detected in the external auditory canal either related to its anterior or posterior wall. In the current study 36.4 % of the external ear patients had osteochondroma as described however, 3D images clarify the lesions, showing the small pedicle/neck of the lesion which was not clear in routine CT images

María et al.,[7] **and Qin et al.,**[8] stated that external ear atresia is the absence of external ear canal being a birth defect, and accompanied by auricle malformation, the High-resolution MSCT (HRCT) of the temporal bone is the method of choice since atretic external auditory canal does not allow visualization of tympanic membrane and middle ear structures, imaging studies are mandatory. Our study included 9.1% of the patients with small deformed auricle and suspected atresia. MSCT study showed external ear atresia with normal middle and inner ear development, this also confirmed by the 3D images that clarify small anatomical details of the middle and inner ear.

So in external ear pathology; MSCT and 3D reconstruction image help in evaluation of the small bony lesions like osteochondroma and exclude congenital anomalies of the middle and inner ear in cases of external ear atresia or small accessory auricle. On the other hand, 2D MSCT image were satisfied for the diagnosis for patients with simple otitis externa.

As regard the middle ear**, Trojanowska et al.,**[6] and **Pasetto et al.,**[1] reported that both CSOM and cholesteatoma have similar symptoms like ear discharge and diminished hearing loss. In addition it is difficult to differentiate by clinical examinations however MSCT plays an important role in the diagnosis.

In our study, 40% of the patients had inflammatory middle ear disease, 62.5% of them had chronic supurative otitis media (CSOM) and 37.5% had cholesteatoma. MSCT findings in our study showed thickening of tympanic membrane in 62.5 %, fluid density in 50% all of them had CSOM, while soft tissue density detected in 50% almost of them had cholesteatoma 37.5%. All patients with cholesteatoma showed erosion or destruction of bony walls, mainly was involving the tegmen tympani and ossicles in addition 13.3% of them showed intracranial extension.

So, in agreement with **Juliano et al.,**[6]**.** For the middle ear pathology we considered MSCT and 3D reconstruction image were the main diagnostic method in differentiating between the otitis media and cholesteatoma as well as evaluation of the middle ear ossicles and intracranial extension. 3D evaluation of the ossicles was of high accuracy with thin MIP and thin VR images give more real images than the 2D MSCT images.

As regard the inner ear**, Juliano et al.,**[9] and **Verbist**[10] reported that 2D MSCT imaging was essentially for evaluation of the bony labyrinth anatomy and exclude congenital causes or other pathological changes. In addition 3D and MPR images clarify the anatomical details and confirm the diagnosis.

In the current study, 31% of the patients included had inner ear problem and suffering from sensory neural hearing loss, however only 16.13% of them showed positive CT findings. 6.46% had congenital anomalies (3.23 % had common cavity and 3.23% had type I incomplete partition of the cochlea) and 9.67% were post cochlear implant evaluation, while the other 83.87% showed normal MSCT examination. So in agreement with **Juliano et al.,**[9] and **Verbist**[10], we found the selected 3D thin MIP and thin VR images showed adequate volumetric evaluations of the cochlea, vestibule and semicircular canals with advantage of rotation in different planes that confirm the diagnosis.

Gomes et al.,[11] **and Kong et al.,**[12] stated that, CT is useful for delineating bony anatomy and identifying potential hazards and contraindications to surgery, such as inner ear dysplasia, also complications related to cochlear implantation include device mal-position or migration, breakage, facial nerve canal dehiscence and stimulation or injury, pneumo-labyrinth, and bone erosion, which are best evaluated with Multiplanar high-spatial resolution CT, and three-dimensional stereoscopic CT images in greater details. This cope with our current study as 9.67% of the patient with inner ear symptoms were for post cochlear implant evaluation, MSCT with selected 3D thin MIP and thin VR images were done and showed accurate delineation of the implant electrode along its course till reaching the cochlea and detect if it is broken, slipped out or need to be more inside the cochlear turns. This beside evaluation of the external and middle ear to exclude other pathological changes that can affect the implant process.

Regarding temporal bone fractures, **Trenkic et al.,**[13]**, Mallina et al.,**[14]**and Duggal et al.,**[15] stated that3D image plays an important role in musculoskeletal imaging especially for trauma. Actually this confirmed in our study as 4% of the patients had fracture were included and 3D image played an important role in clarification and assessment of the fracture along its extension.

On the other hand, **Erdogan et al.**[16] stated that although peri-auricular is not a common location for Dermoid cyst¸ MSCT is mandatory for evaluation of it. This was applied in our study as 2% of the patients included had posterior peri-auricular slowly growing soft tissue swelling. MSCT findings was coping with subcutaneous dermoid cyst in addition no detected intracranial extension or associated bone erosion or destruction. 3D images also confirm the intact underlying bone and gave us images as we see the patient in front using 3D VR images with soft tissue window

Regarding petrous apex lesions, **Abdel Razek and Huang.**[17] reported thatvariable lesionscan involve the petrous apex and described cephalocele cyst as a lesion representing protrusions of arachnoid or dura mater, usually from the Meckel cave, into the petrous apex. Actually 1% of the patients included in our study had similar findings on MSCT examination with 3D thin VR image clarify its location, extent and smooth outline with no evident bony destruction.

Hofmann et al.,[18] had reported that the 2nd common cause of pulsatile tinnitus is the venous normal variants and anomalies after highly vascularized tumors of the temporal bone. Similar findings reported in our study as it included 4% of the patients had pulsatile tinnitus. MSCT examination showed widening of the jugular fossa bony boundaries with suspect smooth bone defect at its lateral wall in 50% of them, 3D images made the bone defect more obvious and confirm the diagnosis of jugular dehiscence. While the other 50% showed associated dilatation of the jugular bulb with no detected masses and diagnosed as jugular bulb ectasia, confirmed by MRI examination which was not included in our study.

Actually the idea of 3D application is the production of additional images, which will have additional diagnostic value and not just to provide pretty picture. Post processing of 3D application of the temporal bone was a time consuming process and need much familiarity with the 2D anatomy. Also, cutting and removing of the bones near small structures is a fine step process to avoid technical artifact which may be diagnosed as bone erosion or defect. Window adjustment played similar rule.

Conclusion

MSCT source images and MPR seems to be satisfied for accurate diagnosis of the temporal bone pathology however 3D reconstructed images played an important role in assessment of the anatomical details of small middle ear and inner ear structures and clarify the bony pathological changes. Further studies for specific pathology will be more beneficial than evaluation of variant pathologies.

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