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Role of High Resolution Computed Tomography in Evaluation of Pathologies of Temporal Bone.

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Abstract

Background: High Resolution Computed Tomography (HRCT), a modification of routine CT, provides a direct visual window in the temporal bone providing minute structural details. Purpose of the present study was to evaluate the normal variations, pathological processes (infections, tumours, trauma and congenital anomalies) and their extent involving the temporal bone along with their complications on HRCT and to correlate these imaging findings surgically, wherever available.

Materials and Methods: The prospective study included 40 patients who were referred to the radiology department with clinically suspected temporal bone or ear pathologies. After detailed clinical examination, the patients were subjected to high resolution computed tomography (HRCT) examination. The imaging findings were correlated with the surgical findings wherever available. The surgical findings were considered as final.

Results: From a total of 40 cases, 83.33% had cholesteatoma. The surgical and radiological findings showed a high level of sensitivity (95.65%) in the identification of cholesteatoma. HRCT provides a good sensitivity of in the identification of changes to the ossicular chain despite the presence of surrounding soft tissue. HRCT was highly informative in identification of erosion of lateral semicircular canal. In diagnosis of facial canal dehiscence HRCT had a low sensitivity. In the evaluation of any congenital abnormality of the ear HRCT proved to be beneficial in depicting the anatomical details.

Conclusion: Good agreement between HRCT and operative findings with respect to soft tissue extension, bony boundaries of tympanum, mastoid pneumatization, status of ossicular chain, facial nerve canal and fistula of lateral semi-circular canal were excellent Hence HRCT plays an important role in pre-operative evaluation, guiding the surgical management.

Keywords: Asom, Cholesteatoma, Chronic suppurative otitis media, Csom, Otitis media.

Introduction

The anatomy of temporal bone is very complex and is further complicated by the small size and three-dimensional orientation of associated structures. Each temporal bone is composed of five osseous parts, the squamous, mastoid, petrous, tympanic, and styloid portions. The petrous temporal bone is a complex structure containing the middle, inner ear and various contained structures such as ossicles. In addition, major vessels and nerves course through it [1].

Radiological evaluation of the temporal bone is difficult owing to complicated anatomical structure of the middle ear and inner ear. Before the advent of computed tomography and magnetic resonance imaging, temporal bone pathologies were evaluated with the help of plain radiograph, polytomography, angiography, and cisternography. Though plain radiograph is an inexpensive imaging modality, it is limited by the overlapping of various bony structures and complex anatomy of the temporal bone.

With the emergence of cross-sectional imaging, Computed tomography and magnetic resonance imaging are the most widely used modalities for evaluation of the temporal bone pathologies. High resolution computed tomography is a modification of routine computed tomography produces images with higher contrast and a better spatial resolution. HRCT has the advantage of excellent topographic visualization, devoid of artifacts from the superimposition of structures. HRCT provides excellent contrast between osseous structures, air and soft tissue in conjunction with high spatial resolution [2].

Aims and objective of this study is to evaluate the congenital, inflammatory, traumatic, and neoplastic conditions affecting the temporal bone with the help of HRCT and to correlate these imaging findings surgically, wherever available.

Material and Methods

This prospective observational study was conducted on 40 patients of varied age group, with sign and symptoms related to temporal bone pathologies. However patients with history of previous surgery and those with electric devices at the skull base, such as cochlear implants were excluded.

All the patients underwent a detailed clinical examination at ENT department followed by high resolution computed tomography temporal bone. They were evaluated with Philips CT 64 Brilliance slice scanner (Brilliance 64, Philips, Netherlands).

Scout films were taken routinely in all patients before starting the scan. Scans were acquired in the helical mode to reduce motion artifacts. Scanning with 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 (FOV), and a 512 x 512 matrix. With the patient in supine position & slight extension of the head, axial projections were obtained by serial thin sections of the temporal bone with the line joining the infra-orbital rim and external auditory meatus perpendicular to the table. The images were reconstructed with a bone algorithm. Coronal and sagittal reformatting was done to a slice thickness of 0.67 mm.

The findings of HRCT were noted and tabulated.

Image Analysis

Scans were evaluated for the following parameters:

- The type, location and extent of lesion.
- The integrity of the ossicular chain, facial nerve canal and labyrinth
- Congenital anomalies

Observations and Results

A total of 40 patients were included in the study. Out of 40 patients, 9 patients were managed conservatively and 31 patients were undergone surgery. Hence correlation of HRCT findings and intra-operative findings could be assessed only for those 31 cases who underwent surgery as well as HRCT. The observations were as follows:

- In this study Majority of patients in the study belonged to the 21– 30 year age group, the youngest patient was 2 years of age and oldest was 63 years old. Male: female ratio was 1.22. The most common presenting symptom was ear discharge. [Table/Fig-1] shows the presenting complaints of patients. The distribution of the temporal bone disease was unsafe CSOM (cholesteatoma) followed by safe CSOM, congenital anomaly, fracture, Anatomical variants and tumor. [Table/Fig-2] shows the HRCT diagnosis of temporal bone pathologies.
- In our study HRCT diagnosis of unsafe CSOM with cholesteatoma was made in 25 patients, where 25 patients underwent surgery. Out of 25 patients, intraoperative findings of cholesteatoma was noted in 22 patients. The other 3 patients were found to have unsafe pathology in the form of granulation without cholesteatoma. Safe CSOM was diagnosed in 9 patients on HRCT. Out of 9 patients 5 underwent surgery, while 4 patients managed conservatively. Out of 5 patients, surgical findings confirmed safe CSOM in 4 patients, while 1 patient was found to have unsafe CSOM during surgery. So HRCT underdiagnosed in 1 (20%) patient. HRCT diagnosis of tumor was made in 1 patient. [Table/Fig-3] shows correlation between HRCT and intraoperative findings regarding type of disease. HRCT showed erosion of scutum, ear ossicles, lateral SCC, facial canal and tegmen tympani. [Table/Fig-4] shows correlation between HRCT and intraoperative findings regarding bone erosion. HRCT showed soft tissue density in middle ear cavity, aditus, antrum and mastoid air cells. [Table/Fig-5] shows correlation between HRCT and intraoperative findings regarding extent of disease.

Discussion

Radiographic assessment of temporal bone is difficult owing to complicated anatomical structure of middle and inner ear. The temporal bone is unique in the sense that many small yet important structures exist within it and having wide range of densities like cortical bone, air spaces, and soft tissues.

HRCT imaging is necessary for assessment of pathology prior to surgical exploration regarding location, extent and complication of the disease. HRCT, depicts the ossicular and inner ear abnormality in patients with congenital malformation. It helps in characterizing type and extent of neoplastic lesions. HRCT helps in detection of middle ear infections and their complications [3]. Also pre-surgical knowledge of normal variations are crucial when performing operations, and the pre-operative high resolution CT scan is useful in this regard.

A total of 40 patients were taken in this study, the age of patients ranged from 2 years to 63 years. Mean age of patients was 25.73 years. In this study, we found that the majority of patients were aged between 21-30 years (35%) which are similar to findings by Datta et al [4] and Gerami et al [5]. Thus, most of the studies targeted to study temporal bone pathologies or normal variations have reported the mean age of patients between 25 to 30 years.

In our study 22 (55%) patients were male and 18 (45%) were female. Male to female ratio was 1.22%. Male female ratio is similar to a study which was conducted by

Rogha M et al [6] that included 60 patients with 44.4% female and 55.6 % male.

Majority of patients 35 (87.5%) had unilateral involvement, while bilateral involvement was noted in 5 (12.5%) patients. In a study conducted by Gomaa et al [7] bilateral involvement was noted only in 3.57%.

Ear discharge and hearing loss are usually the most common presenting symptoms of patients with temporal bone pathologies. In our study, a total of 37 (92.5%) patients had otorrhoea, 32 (80%) had hearing loss and 14 (35%) had earache as presenting symptoms. In a study by Gomaa et al [7] chronic ear discharge with hearing loss was the main clinical presentation (60.7%).

According to Mafee et al [8] the hallmark of cholesteatoma on HRCT is a soft tissue mass in attic and mastoid antrum associated with smooth bony expansion, scalloping of the mastoid, erosion of lateral wall of attic and erosion of ossicles [Table/Fig-6]. In our study HRCT diagnosis of unsafe CSOM with cholesteatoma was made in 25 patients, where 25 patients underwent surgery. A good correlation of 88% was found between HRCT and operative findings in unsafe CSOM patient. According to Mafee et al [9] comparing the imaging changes with findings at operation they found agreement between the radiographic interpretation and surgical findings in 90% of the cases. Sensitivity of 95.65% and specificity of 62.5% was noted in our study in pre-operative HRCT diagnosis of cholesteatoma. We could correlate these findings with Jackler et al [10] who concluded sensitivity of 87% and specificity of 66%. Thukral et al [11] also reported the sensitivity (89.29%) and specificity (77.22%) of HRCT to diagnose cholesteatoma preoperatively in their study.

Safe CSOM was diagnosed in 9 patients on HRCT [Table/Fig-7]. Out of 9 patients 5 underwent surgery, while 4 patients managed conservatively. Out of 5 patients surgical findings confirmed safe CSOM in 4 patients, while 1 patient was found to have unsafe CSOM during surgery. So HRCT under diagnosed in 1 (20%) patient, which was confirmed as unsafe CSOM during surgery. Hence, there was a correlation of 80% between preoperative HRCT diagnosis and operative findings in safe CSOM. We could correlate these findings with a study by Thukral et al [11] who concluded correlation of 76.92 % between preoperative HRCT diagnosis and operative findings. In our study, HRCT temporal bone was found to be 100% sensitive and 95.6% specific in identifying safe CSOM.

Knowledge of the mastoid pneumatization aid in the planning of surgical approach (e.g. whether to do canal wall down or up type of surgery). In majority of the adult cholesteatoma patients, mastoid air cells are very few in number and sclerotic. Mastoid was found to be well-pneumatized in 13 (41.9%), sclerotic in 14 (45.2%) and diploic in 4 (12.9%) patient in HRCT as well as intra-operatively. Hence HRCT is 100% sensitive and specific to know the type of mastoid pneumatization. This is in agreement with findings of Petros V Vlastarakos et al [12] who found strong agreement with HRCT findings and those intraoperatively in case of mastoid-air cell complex.

In this present study the sensitivity of HRCT for detecting soft tissue density in epitympanum was 90.91%, mesotympanum was 100% and hypotympanum was 100%. Similarly, the specificity of HRCT scan for detecting soft tissue density in epitympanum was 100%, mesotympanum was 90.91% and hypotympanum was 86.96%. These findings are consistent with the findings of study by Sirigiri RR et al [13] and Garber et al [14].

Sensitivity of HRCT for detecting soft tissue density in aditus was 100% which is similar to observations by

Sirigiri RR et al [13] and specificity was 100% which is higher compared to 75% seen by Sirigiri RR et al [13]. In the antrum, HRCT sensitivity was 95.24%, which is similar to observations by Sirigiri RR et al [13] and specificity 100% which is higher as compared to 66% seen by Sirigiri RR et al.[13] In mastoid air cells, HRCT sensitivity was 89.47% and specificity was100% which is similar to observations by Gerami H et al [5].

HRCT is found to be most accurate in identifying ossicular erosion. In our study, HRCT showed erosion of scutum [Table/Fig-8]. in 18 patients with a sensitivity of 88.24% and specificity of 78.57%, which is comparable with study conducted by Rogha M et al [6].

HRCT detected erosion in Malleus correctly in all 6 cases. So HRCT is 100% sensitive and specific to diagnose Malleus erosion. This is correlating with studies by Zhang X et al [15], Rocher P et al [16], and Chee NW et al [17]. HRCT detected erosion in Incus in 16 whereas intraoperatively it was present in 14 cases. So HRCT was 92.9% sensitive and 83.3% specific which correlates with studies by Roghe M et al [6] having sensitivity of 90.6% and specificity of 50%. HRCT detected erosion in Stapes in 8 cases, intraoperative erosion was found in 6 cases. So HRCT was 100% sensitive and 92.31% specific. This is similar to studies by O'Donoghue et al [18] but contrasts to studies by Zhang X et al [15] who found that HRCT was poor in detecting Stapes erosion.

HRCT was able to identify erosion of lateral semicircular canal in 3 patients, while intraoperative findings showed lateral semicircular canal erosion in 2 patients with a sensitivity of 100% and specificity of 96.55%. The positive predictive value and negative predictive value of HRCT was found to be 66.67% and 100% respectively. The findings were comparable to a study conducted by Prata et al [19] where the sensitivity and specificity was found to be 100% and 96.67% respectively and the positive and negative predictive values were 50% and 100% respectively.

On comparing the HRCT findings with Intra operative findings for identifying tegmen tympani erosion in the present study, we found the sensitivity 66.67%, specificity 100%, positive predictive value 100%, and negative predictive value 96,55%. A similar specificity rate of 95% was reported by Gerami et al [5] and a specificity rate of 91.93% and negative predictive value of 100% were also reported by Prata et al [19] and Datta et al [4]. O'Donoghue et al [20] reported a sensitivity of 50% in identifying tegmen tympani erosion.

HRCT showed facial canal dehiscence in 2 patients, while facial canal dehiscence was found to be present in 3 patients intraoperatively. We calculated a sensitivity of 66.67% and specificity of 100% for HRCT to diagnose facial canal dehiscence. This low sensitivity and relatively high specificity in our study could be correlated with study conducted by Rai et al [21] with sensitivity and specificity of 33.33% and 100% respectively. Gaurano et al [22] stated that preoperative demonstration of facial nerve canal involvement was often difficult not only because of the small size of the facial nerve canal, but also due to its oblique orientation and the presence of developmental dehiscence, particularly when abutted by the soft tissue. The most common site for erosion is tympanic portion of the fallopian canal. Literature reports on facial nerve erosion have given contradictory findings. Some authors reported HRCT over diagnosed facial canal erosion. While others reported that HRCT under diagnosed facial canal erosion.

In present study, 1 case (2.5%) was diagnosed as tumor on HRCT temporal bone. Tumor constitute 2.5% cases of our study, which is not correlated with the study of GAS

Lloyd et al [23] which claimed tumors to be the most frequent lesions. On the basis of HRCT findings diagnosis of Acoustic Schwannoma was made in our study [Table/Fig-9]. This patient underwent surgery and diagnosis was confirmed by histopathological report. Acoustic neuroma was the most common internal auditory canal and / or CP angle lesion in a study by P Wolf et al [24] and GAS Lloyd [23] There was a correlation of 100% between HRCT and operative findings in tumor. In our study, HRCT temporal bone was found to be 100% sensitive and 100% specific in identifying tumor.

In this study, 2 patients (5%) were diagnosed as congenital anomaly on HRCT temporal bone. On the basis of HRCT findings diagnosis of EAC atresia was made in both patient [Table/Fig-10]. In one patient ossicular chain abnormality was seen in association with EAC atresia while in another patient of EAC atresia, ossicular chain found normal. The most common external auditory canal (EAC) anomaly was its atresia in a study by JD Swartz et al [25], PD Philips et al [26] and DW Chakeres et al [27]. The main role of imaging in congenital anomalies is to identify the type of anomaly and determine the surgical correction ability [28]. If surgical correction of EAC atresia is to be done to improve hearing, normal inner ear structures and adequate middle ear cleft are necessary. It is important to evaluate the thickness of atresia plate, associated ossicular abnormalities, status of middle ear cleft, status of inner ear, course of facial nerve canal and position of sigmoid sinus and mastoid pneumatisation which is accurately depicted on HRCT.[28] The present study correlated well with findings of Swartz et al [29]. The diagnostic gain achieved by HRCT in case of congenital anomalies is to identify the type of anomaly and to determine its surgical correction ability.

In this study HRCT diagnosis of normal variant was made in 1 (2.5%) patient. According to characterstic HRCT findings diagnosis of dehiscent jugular bulb was made [Table/Fig-11]. The jugular bulb is the point where the sigmoid sinus feeds into the jugular vein. It is normally located below the posterior part of the middle-ear floor. A dehiscent jugular bulb is susceptible to injury during tympanomastoid surgery, which can result in unexpected haemorrhage. Knowledge of such variations is crucial prior to undertaking surgery to avoid unnecessary and avoidable complications.

In our study 2 cases (5%) were having traumatic injuries to the temporal bone. On the basis of HRCT findings diagnosis of longitudinal fracture of temporal bone was made in both patient. In one patient fracture of mastoid part which is extending to petrous part [Table/Fig-12], while in another patient fracture of squamous part of Temporal bone was found. Both patients were managed conservatively. HRCT has got a role not only in diagnosis but also in accurately delineating the finer details of fracture line. Delineation of more subtle fractures of the petrous bone and thorough evaluation of associated findings are possible with HRCT. And also, the three dimensional capability of HRCT offers a specific advantage over conventional CT. Contrary to high-resolution CT, conventional CT is inefficient in diagnostic as well as for screening purposes.

For those patients who need surgical intervention for any of the complications of temporal bone injury, pre-operative HRCT is definitely needed to plan the surgical approach. The importance of early identification of these temporal bone injuries and their detailed description avoids some of the delayed complications of these injuries which may have a strong impact on the quality of life and sometimes may cause mortality also.

Thus, the present study has shown that HRCT plays an important role in evaluation of temporal bone, its anatomical variations, congenital anomalies, various infective pathologies and their complications and temporal bone fractures. HRCT is a non-invasive method to diagnose temporal bone pathologies and play an important role in the pre-operative planning.

Fig 1: Clinical symptoms of patients studied

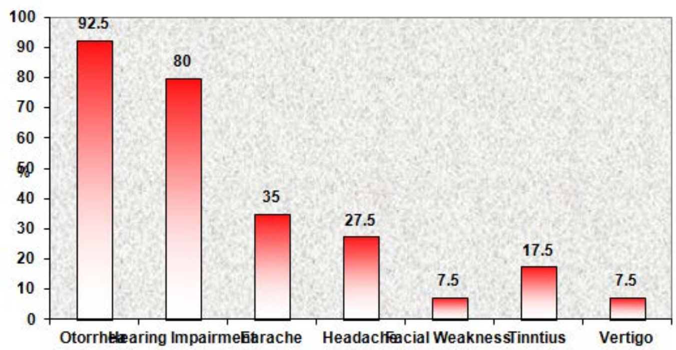


Fig 1: Clinical symptoms of patients studied

HRCT Diagnosis	No.	%
Anatomical Variant (DJB)	1	2.50
Cholesteatoma	25	62.50
Cong. Anomaly	2	5.00
Safe CSOM	9	22.50
Temporal Bone Fracture	2	5.00
Tumor (Acoustic Schwannoma)	1	2.50
Total	40	100.00

Table 1: HRCT diagnosis of Temporal bone pathologies

Type of abnormality	HRCT finding	Intra operative finding	False Positive	False Negative	Sensitivity	Specificity	PPV	NPV
Cholesteatoma	25	22	3	0	95.65	62.5	88.00	83.33
Safe CSOM	9	4	1	0	100.00	95.6	80.00	100.00
Tumor	1	1	0	0	100.00	100.00	100.00	100.00

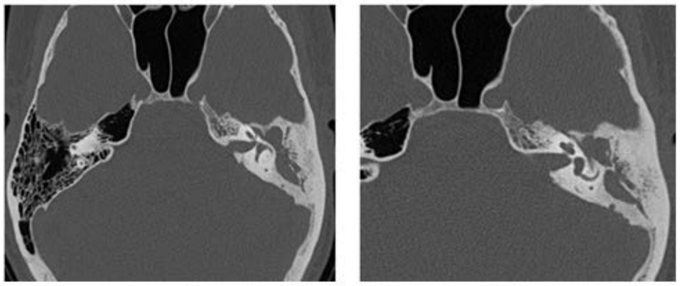
Table 2: Correlation between HRCT findings and Intra-operative findings regarding type of disease

Extent	HRCT finding	Intra-operative finding	False Positive	False Negative	Sensitivity	Specificity	PPV	NPV
Epitympanum	20	22	0	2	90.91	100.00	100.00	81.82
Mesotympanum	11	9	2	0	100.00	90.91	81.82	100.00
Hypotympanum	11	8	3	0	100.00	86.96	72.73	100.00
Aditus	19	19	0	0	100.00	100.00	100.00	100.00
Antrum	20	21	0	1	95.24	100.00	100.00	90.91
Mastoid air cells	17	19	0	2	89.47	100.00	100.00	85.71

Table 3: Correlation between HRCT findings and Intra-operative findings regarding extent of the disease.

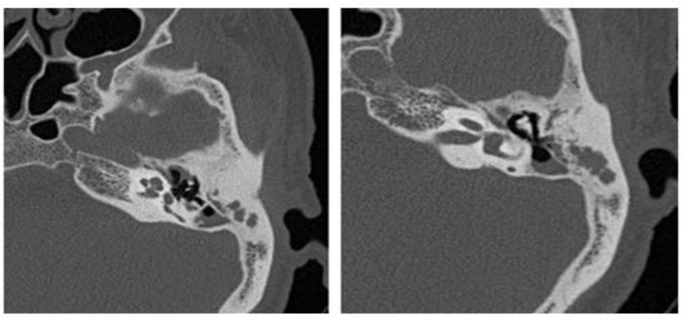
Erosion	HRCT finding	Intra-operative finding	False Positive	False Negative	Sensitivity	Specificity	PPV	NPV
Incus	16	14	3	1	92.86	83.33	81.25	93.75
Malleus	6	6	0	0	100.00	100.00	100.00	100.00
Stapes	8	6	2	0	100.00	92.31	75.00	100.00
Scutum Erosion	18	17	3	2	88.24	78.57	83.33	84.62
Lateral SCC Erosion	3	2	1	0	100.00	96.55	66.67	100.00
Facial Canal Erosion	2	3	0	1	66.67	100.00	100.00	96.55
Tegmen Tympani Erosion	2	3	0	1	66.67	100.00	100.00	96.55

Table 4: Correlation between HRCT findings and Intra-operative findings regarding bone erosion



(A) (B)

Fig.2: (A) and (B) axial HRCT temporal bone, show left sided cholesteatoma with ossicular chain disruption and erosion of tympanic segment of facial nerve canal, s/o left extensive cholesteatoma



(A) (B)

Fig. 3: (A) and (B) Axial HRCT images showed Soft tissue thickening is seen in right middle ear and mastoid air cells, mastoid septations are Eroded. No cortical breach is seen. Intact facial nerve canal and No destruction of middle ear ossicles is seen, s/o safe variety of CSOM

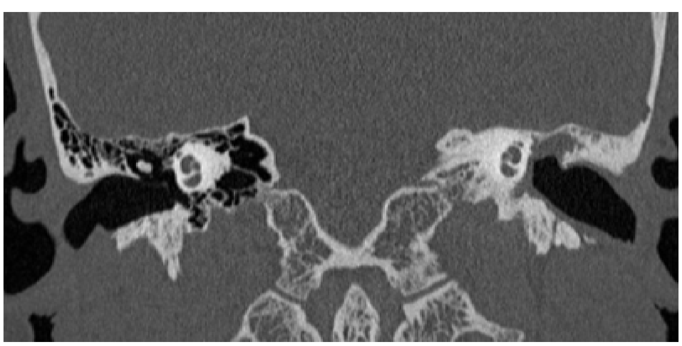


Fig. 4 : Coronal HRCT image shows non-dependent soft tissue density lesion in left Prussak's space extending into left epitympanic space with erosion of scutum s/o Left Cholesteatoma with erosion of scutum

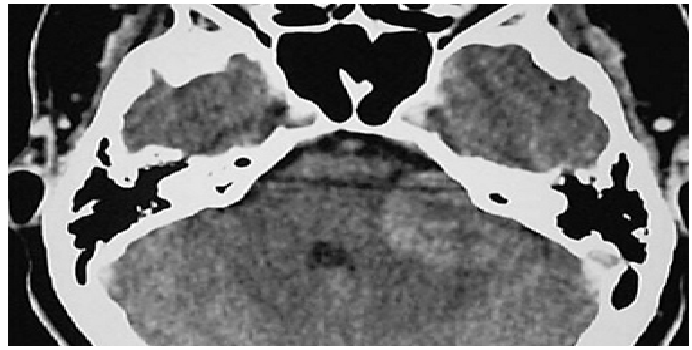
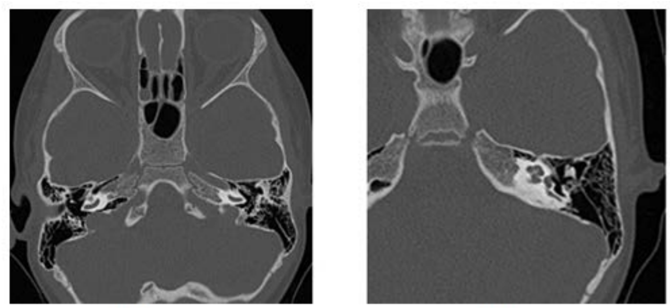


Fig. 5: Axial CT section of the brain demonstrates heterogeneously enhancing left CP angle mass f/s/o Left sided Acoustic schwannoma



(A) (B)

Fig. 6: Left External Auditory Canal Atresia with intact middle ear ossicles (A) and (B) Axial HRCT images shows left side atresia of external auditory canal with normal middle ear ossicles

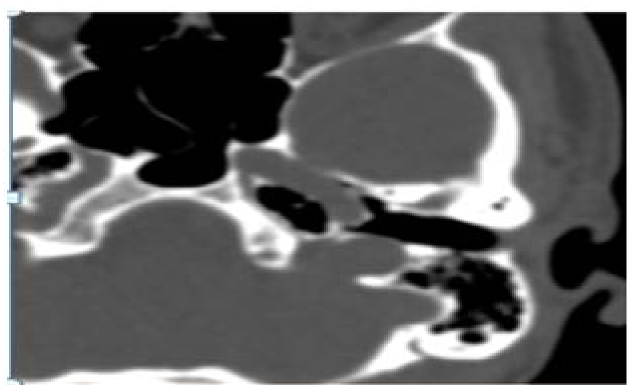


Fig 7: Axial HRCT image shows Large left jugular bulb and deficient sigmoid plate allowing the jugular vein to almost protrude Into the middle ear s/o Left side Dehiscent jugular bulb

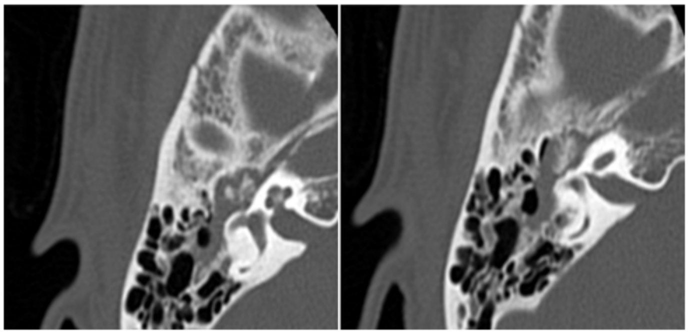


Fig. 8 : Right Temporal bone fracture Axial HRCT image shows Linear non displaced fracture is seen involving right squamous temporal bone.

Conclusion

The results of present study thus indicated that HRCT is the single most important imaging tool to evaluate various congenital, inflammatory, traumatic, and neoplastic pathologies of the temporal bone. In this study, Correlation between HRCT and surgical finding with respect to soft tissue extension, bony boundaries of tympanum, mastoid pneumatization, status of ossicular chain, facial nerve canal and fistula of lateral semi-circular canal were excellent Hence it plays an important role in pre-operative evaluation, guiding the surgical management. Overall, the results of the present study showed a good agreement between HRCT and operative findings.

Limitations

Limitations of the present study:

- The limited sample size in this study could have affected the interpretation of the obtained result. Clearly, more studies involving a larger sample size are warranted in future.
- Inter-observer variability was not assessed in the present study.

Abbreviations

CT	:	Computed Tomography
CECT	:	Contrast Enhanced Computed Tomography
HRCT	:	High Resolution Computed Tomography
MRI	:	Magnetic Resonance Imaging
CSOM	:	Chronic Suppurative Otitis Media
SNHL	:	Sensori neural Hearing Loss
EAC	:	External Auditory Canal
CPA	:	Cerebellopontine angle
PPV	:	Positive predictive value
NPV	:	Negative predictive value
SCC	:	Semicircular canal
ANSD	:	Auditory neuropathy spectrum disorder
IAC	:	Internal auditory canal
DJB	:	Dehiscent jugular bulb
EACA	:	External auditory canal atresia
AS	:	Acoustic schwannomas

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