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ORIGINAL ARTICLE

Revisiting Correlation Between Pre Operative High Resolution Computed Tomography and Operative Findings in Attico Antral Disease

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Abstract (1) To correlate the findings of high resolution computed tomography (HRCT) scans with operative findings in chronic otitis media (attico antral disease). (2) To assess the role of HRCT in chronic otitis media (attico antral disease). This prospective observational study undertaken at a tertiary level teaching hospital included 50 patients of chronic otitis media (attico antral disease) who underwent pre-operative HRCT scanning and the findings were compared with the operative findings and correlation between the two was assessed with appropriate statistical methods. HRCT findings correlated well for the status of malleus and incus, facial nerve canal, lateral semicircular canal, and sinus plate but were less accurate for stapes and tegmen plate. As for disease extent and prediction of cholesteatoma the degree of correlation was site dependent being greater in mastoid air cell system and epitympanum and lesser in mesotympanum and hypotympanum. HRCT despite of its value in management of chronic otitis media has its drawbacks and limitations. CT's accuracy of prediction in some aspects of the disease varies with the site of pathology and this point must always be kept in mind by the operating surgeon. We suggest that each health care centre should establish their own correlative indices for HRCT temporal bone imaging in COM. HRCT cannot be entirely relied upon in management of chronic otitis media
patients. However against the backdrop of improved radiological skills in interpreting temporal bone ct images, improved CT machines and importantly the growing concern over medicolegal issues, the role of pre operative CT scan in COM is much more than what was thought previously. Undoubtedly, it is a very useful 'aid' to management BUT a well-trained, experienced and alert surgeon is the *key* for an accurate diagnosis and successful management of chronic otitis media (attico-antral disease).

Keywords
High resolution computed tomography (HRCT) ·
Chronic otitis media · Attico antral · Cholesteatoma

Introduction

In the late 1970s and early 1980s the use of computed tomography (CT) in patients of chronic otitis media (COM) had begun. Since then it has been a subject of debate as to which cases of COM should undergo a pre-operative CT scanning. In this context earlier studies were carried out by Jackler et al. [1] followed by O'Reilly et al. [2], Walshe et al. [3], Banerjee et al. [4] and more recently Chatterjee and Khanna [5].

While quite a few studies have been done to compare the pre operative CT scan findings to the operative findings in cases of COM, the result of this equation however, cannot be considered as a 'constant' for universal use as there are many variables associated with 'machine' as well as 'men' namely the radiologist and the operating surgeon. It is therefore essential to not only revisit this equation from time to time but also a particular centre of healthcare should have its own correlative indices.

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Indeed, the usefulness of CT Scanning depends upon its ability to correctly interpret various aspects of the disease. This ability has been consistently improving over time owing to improved radiological skills in interpreting temporal bone CT images. The above observation finds its mention in the work of O'Reilly et al. [2] who emphasised that their results would have improved if their study had continued further. The other reason is the newer improved CT machines which provide better images than what the earlier machines had offered. Moreover the statistical methods of analysis which were used in many of the previous studies were rather inadequate in conveying the usefulness of CT scan in the present context. In fact, these statistical indicators on many occasions were misleading. Apart from other statistical measures we included predictive values for data analysis as we find this to be the most appropriate index to assess the usefulness of CT scan. Our view is also shared by O'Reilly et al. [2]. Although a few studies did mention the predictive values but did not do so for all the parameters that were radiologically analysed. This discordance in the method of statistical analysis makes it difficult to compare findings among different authors. Hence the present study would serve as a statistical template for similar studies being conducted in future and thus would facilitate comparison of findings among different authors.

This study was therefore undertaken with the intent to review the correlation between CT and operative findings and thereby re assess the usefulness of CT scan in chronic otitis media (attico antral disease) against the backdrop of improved technology, more skilled radiologists, and the rising concerns over medicolegal issues that arise following inadvertent complications during surgery.

Materials and Methods

This prospective observational study was undertaken at a tertiary level teaching hospital from October 2015 to December 2017 and 50 patients with chronic otitis media (attico antral disease) were included but those with a previous history of ear surgery, history of temporal bone fracture, those having a neoplastic or granulomatous disease of the temporal bone, and those who were not fit for surgery (such as pregnancy or ischaemic heart disease) were excluded. Diagnosis of chronic otitis media (attico antral disease) was on clinical basis.

After a detailed history and examination and relevant investigations, these patients underwent HRCT temporal bone scan on a multislice CT scanner (Siemens Somatom Emotion) with 0.6 mm cuts and the findings were then reported by a single experienced radiologist. The radiologist was specifically asked to comment on the following

points: (1) Status of malleus, incus, stapes superstructure, (2) facial canal dehiscence, (3) lateral semicircular canal dehiscence, (4) tegmen, (5) sigmoid sinus plate, (6) disease extent, (7) predicting cholesteatoma. These findings were then compared with the intra operative findings. Considering the intra operative findings as gold standard sensitivity, specificity and predictive values were calculated.

Ethical clearance for the above research protocol was obtained by the institutional ethics committee.

Results

Specificity for ossicular chain erosion varied between 62.5 and 100% and sensitivity varied between 65.38 and 88.57% being greater for malleus and incus and lesser for stapes. For facial canal dehiscence CT successfully detected 11 out of 12 cases but gave 4 false positive results. For lateral semicircular canal erosion, all the 5 cases were detected by CT with 1 false positive result. For tegmen erosion, CT missed 3 cases out of 8 while giving 7 false positive results. Out of the 9 cases of sinus plate erosion 7 were correctly predicted by CT while missing 2 cases (Table 1).

CT was accurate in epitympanum and mastoid disease but sensitivity and specificity fell in mesotympanum and hypotympanum (Table 2).

When soft tissue density with bone erosion was used as the CT criteria for predicting cholesteatoma it was found consistent in mastoid air cell system and epitympanum (82.85 and 78.79% respectively) but this consistency was not seen in mesotympanum and hypotympanum (42.86 and 25% respectively) (Table 3).

Discussion

Malleus erosion was seen intra operatively in 70% of the cases. CT scan was found to be 88.57% sensitive and 66.67% specific for detecting malleus erosion.

Incus was found eroded in 90% of the cases intraoperatively. CT scan was found to be 84.44% sensitive and 100% specific in diagnosing incus erosion.

Stapes superstructure was eroded in 92% of cases intraoperatively. CT was found to be 65.38% sensitive and 62.50% specific for diagnosing stapes erosion.

Since most of the studies do not mention their results for each ossicle individually, an appropriate comparison of findings on ossicular erosion becomes difficult.

The accuracy of CT scan in diagnosing ossicular erosion varies among authors. While Gerami et al. [6] reported a sensitivity of 92% and specificity of 54% in diagnosing ossicular bone erosion, Jackler et al. [1] could predict ossicular erosion in only 7.1% of the cases.

Table 1 Correlating findings of HRCT with Intraoperative Observations

	CT		OP		TP	FP	TN	FN	Sn (%)	Sp (%)	Predictive values (95% confidence interval)	
	N	E	N	E							PPV (%)	NPV (%)
Malleus	16	34	15	35	31	5	10	4	88.57	66.67	86.11 (75.01–92.76)	71.43 (48.18–87.05)
Incus	11	39	5	45	38	0	5	7	84.44	100	100	41.67 (26.56–58.52)
Stapes superstructure	24	26	25	25	17	9	15	9	65.38	62.50	65.38 (51.22–77.27)	62.50 (47.46–75.46)
FC	35	15	38	12	11	4	34	1	91.67	89.47	73.33 (51.73–87.59)	97.14 (83.84–99.55)
LSCC	44	6	45	5	5	1	44	0	100	97.78	83.33 (41.86–97.20)	100
Tegmen	38	12	42	8	5	7	35	3	62.50	83.33	41.67 (23.15–62.88)	92.11 (82.52–96.65)
SSP	37	13	41	9	7	6	35	2	77.78	85.27	53.85 (34.00–72.55)	94.59 (83.66–98.36)

CT computed tomography, *OP* operative, *TP* true positive, *FP* false positive, *FN* false negative, *Sn* sensitivity, *Sp* specificity, *N* normal, *E* ERODED, *FC* facial canal, *LSCC* lateral semicircular canal, *SSP* sigmoid sinus plate, *PPV* positive predictive value and *NPV* negative predictive value

Table 2 Correlating the disease extent

Disease extent	TP	TN	FP	FN	Sn (%)	Sp (%)	Predictive values (95% confidence interval)	
							PPV (%)	NPV (%)
Mastoid	45	3	2	0	100	60	95.74 (88.49–98.5)	100
Epitympanum	47	3	0	0	100	100	100	100
Mesotympanum	30	9	5	6	83.33	64.29	85.71 (74.53–92.48)	60 (39.59–77.45)
Hypotympanum	16	22	11	1	94.12	66.67	59.26 (46.95–70.5)	95.65 (76.39–99.34)

TP true positive, *TN* true negative, *FP* false positive, *FN* false negative, *Sn* sensitivity, *Sp* specificity, *PPV* positive predictive value and *NPV* negative predictive value

Table 3 Predicting cholesteatoma

	CT (STD + E)	Operative findings		%
		CH	NOT CH	
Mastoid	35	29	6	82.85
Epitympanum	33	26	7	78.79
Mesotympanum	7	3	4	42.86
Hypotympanum	4	1	3	25

CT computed tomography, *STD* soft tissue density, *E* bone erosion and *CH* cholesteatoma

Jackler et al. [1] mentioned that stapes appeared as a structure of soft tissue density in the oval window niche. For this reason it was not possible to distinguish between destruction of stapes and its mere envelopment by soft tissue.

Phelps and Wright [7] doubted that CT could reliably demonstrate the ossicular chain because of the combination of partial volume averaging and tissue silhouetting.

Evaluating the *facial canal* preoperatively can help the surgeon to understand the relationship of the canal with the surrounding pathology which would help him avoid inadvertent iatrogenic injury to facial nerve and would also give information about any preexisting dehiscence or erosion.

In our study, CT could detect 11 out of the 12 cases that were found to have a dehiscent facial canal intraoperatively. However, it also gave false positive result in 4 cases making it 91.67% sensitive but 89.47% specific in diagnosing the facial nerve canal dehiscence. This overdiagnosis of facial nerve canal dehiscence can be attributed to the partial volume averaging of facial nerve canal with the surrounding tissue.

Our findings are comparable to those of Gaurano and Joharjy [8] who found 92% agreement between CT and operative findings in diagnosing facial nerve canal dehiscence. Sirigiri and Dwaraknath [9] reported sensitivity of 60% and specificity of 90% in diagnosing facial nerve canal dehiscence.

O'Reilly et al. [2] mentions that when the soft tissue is overlying the facial nerve canal, it causes loss of contrast gradient obscuring a small dehiscence. Similar problems were also encountered by Jackler et al. [1] and Mafee et al. [10]. This contrast in our findings and those of the older studies mentioned above is probably a reflection of the improvement in the radiologists' skills in interpreting temporal bone CT images that has taken place over time and also owing to improved CT machines. This is precisely the point that was initially stressed upon in the present study.

Lateral Semicircular canal was found to be eroded in 5 cases (10%) intraoperatively. CT scan could detect all of these 5 cases but gave 1 false positive result making it 100% sensitive but 97.8% specific.

If lateral semicircular canal fistula is covered by cholesteatoma (Fig. 1) the patient might not present with vertigo, but on disease removal might become vertiginous post operatively. If a pre-operative CT scan demonstrating this complication is not performed then this might invite medicolegal issues.

Chee and Tan [11] also observed similar findings in their study where CT scan correctly predicted all the 5 cases of lateral semicircular canal fistula and gave 1 false positive result. Hence CT showed 100% sensitivity. Similar to our study Bates et al. [12] also found 10% of their patients (5 of the 50 cases) having a labyrinthine fistula.

Bates et al. [12] observed that the problem in coming across an erosion inadvertently is that the inner ear is more likely to be damaged by mechanical trauma or suctioning

Fig. 1 Lateral semicircular canal fistula (encircled) correctly diagnosed on CT

resulting in a sudden loss of perilymph. They report that incidence of a surgically induced dead ear when a fistula has been found at operation, varies and ranges from 6 to 37%. They further add that it is likely that many unexplained cases of dead ear following surgery occur because of unknown and undiscovered fistulae. Hearing was preserved in all the cases having fistulae in their series of cases.

Tegmen was found to be eroded in 8 cases intraoperatively. CT scan was able to detect 5 out of the 8 cases. However, there were 7 cases in which erosion was reported but was not found intraoperatively.

Our observation is similar to O'Reilly et al. [2] who found that 5 out of 11 cases were detected by CT and 6 cases in which CT reported erosion of tegmen were found to be intact intraoperatively. Similar observations were also made by Berry et al. [13] who found 3 false positive cases in their series of 30 cases.

The tegmen being a very thin structure is prone to the partial volume averaging which is reflected by this observation of high false positive result. Also a rarefied and demineralised bone can be reported as erosion on CT. However, surgically, erosion is said to be present only when the dura is exposed (Figs. 2, 3).

Sinus plate in our study was found to be eroded in 9 cases (18%) intraoperatively. This incidence of sinus plate erosion in our series of cases is similar to Rai [14] who reported it to be 18% in their study.

CT scan was found to be 77.78% sensitive and 85.37% specific in diagnosing erosion of sinus plate. This is similar to observation made by Rai [14] who reported a sensitivity of 75%.

Our observation is in contrast to Vlastarakos et al. [15] who reported that the specificity of CT scan in recognizing an unexposed sigmoid sinus reaches an absolute 100%.

Park et al. [16] proposed that Hounsfield Unit could be used to differentiate between cholesteatoma and inflammatory granulation tissue. They observed that there was a statistically significant improvement in the radiological diagnosis of cholesteatoma on CT after including Hounsfield unit. However, Leighton et al. [17] have mentioned that soft tissue appearance does not differ whether it is cholesteatoma or granulation tissue. Gadolinium enhanced MRI can distinguish between cholesteatoma, granulation tissue and fluid or cholesterol granuloma in the middle ear.

Jackler et al. [1] could accurately predict *cholesteatoma* based on the presence of soft tissue density with associated bony erosion in 78.6% of their cases. Using the same criteria O'Reilly et al. [2] detected 23 out of 29 cases (79%) of cholesteatoma in their series of cases.

Using the same criteria as Jackler and O'Reilly we found that the accuracy of prediction was higher in mastoid air cell system (29/35 cases) and epitympanum (27/33
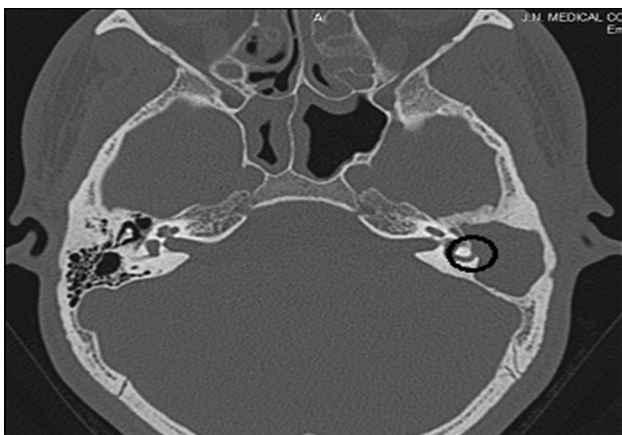
Fig. 2 Tegmen (encircled) in this case was reported as breached but intraoperative was found intact (an example of partial volume averaging)

Fig. 3 Tegmen (encircled) correctly reported as breached in this case

cases) but lower in mesotympanum (3/7 cases) and hypotympanum (1/4 cases).

It is thus evident that the above criteria for predicting cholesteatoma is site dependent being fairly accurate in mastoid air cell system and epitympanum but accuracy falls in mesotympanum and hypotympanum.

Fall in accuracy in mesotympanum can be attributed to the fact that the long process of incus and stapes superstructure has got a delicate structure and location [18] and hence is prone to necrosis even with milder degree of inflammation and not necessarily due to cholesteatoma.

The above observation is supported by the present study in which 90% of cases had a necrosed incus and 92% of cases had a necrosed stapes superstructure.

Epitympanum and mesotympanum have structures such as tegmen, facial canal, and ossicles. Analyzing these structures predicting erosion becomes easier. Hypotympanum in this regard is relatively vacant thereby making prediction of erosion difficult and at the same time highly subjective. This probably accounts for the fall in accuracy in hypotympanum.

The *extent of disease* as predicted by CT was overall consistent with the operative findings, as far as disease extending to epitympanum and mastoid air cell system was concerned. Nonetheless there were 2 false positive reports for mastoid disease. However in mesotympanum 11 cases (6 false negative and 5 false positive) were incorrectly reported. This fallacy might be because of the fact that unlike a radiologist who has the privilege of using line markers on the console to exactly demarcate the limit of pathology, the surgeon's decision is based on his visual judgment and thus a pathology marginally extending into mesotympanum might be interpreted as limited to epitympanum and that limited to epitympanum might be interpreted as extending to mesotympanum. Moreover in hypotympanum there were 11 falsely reported cases of presence of disease. Besides the above mentioned explanation this can be attributed to the fact the hypotympanum might be having a fluid collection which got suctioned intraoperatively and hence hypotympanum was found disease free. Taking into account the above explanations, CT scan would be considered fairly consistent in predicting the

extent of disease. This is in accordance with the observations of Phelps and Wright [7], Walsh et al. [3] and Banerjee et al. [4].

Conclusions

It is thus seen that HRCT was fairly consistent in predicting certain aspects of the disease while being less consistent in the others. CT's accuracy of prediction in some aspects of the disease varies with the site of pathology and this point must always be kept in mind by the operating surgeon. We suggest that each health care centre should establish their own correlative indices for HRCT temporal bone imaging in COM. Overall it can be concluded that HRCT plays an important role in planning the surgical approach by demonstrating the anatomy of temporal bone and structures within it, also their variations in a particular patient as well as the extent of disease. Furthermore a prior knowledge of an impending complication and ossicular status helps in patient counseling explaining to him the risks involved and the probable outcomes and benefits. For instance hearing reconstruction would be of greater benefit to a patient with an intact stapes superstructure than the one in which it is absent [19]. A well informed consent in this regard would avoid medicolegal issues that may arise due to a complication that the patient was not informed of. Thus HRCT of the temporal bone due to its varying degree of accuracy in predicting the relevant information in cases of chronic otitis media (attico-antral disease), cannot be entirely relied upon. However against the backdrop of improved radiological skills in interpreting temporal bone ct images, improved CT machines & importantly the growing concern over medicolegal issues, the role of pre operative CT scan in COM is much more than what was thought previously. Undoubtedly, it is a very useful 'aid' to management BUT a well-trained, experienced and alert surgeon is the *key* for an accurate diagnosis and successful management of chronic otitis media (attico-antral disease).

Compliance with Ethical Standards

Conflicts of interest The authors declare that they have no conflicts of interest.

Ethical approval All procedures performed were in accordance with the ethical standards of the institutional ethics committee and with the 1964 helsinki declaration and its later amendments or comparable ethical standards.

Informed consent All participants were adequately informed about the procedure and an informed written consent was taken and the participants were then recruited for the study.

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