



Dominador B. Toral, MD
Chris Robinson D. Laganao, MD

Department of ENT-Head and Neck Surgery
Southern Philippines Medical Center

Pre-Operative Temporal Bone CT Scan Readings and Intraoperative Findings During Mastoidectomy

ABSTRACT

Objective: To determine the correlation between pre-operative in-house temporal bone CT scan readings and intraoperative findings during mastoidectomy for cholesteatoma in a tertiary government hospital from January 2018 to December 2019.

Methods:

Design: Review of Records

Setting: Tertiary Government Hospital

Participants: A total of 25 charts were included in the study. Surgical memoranda containing intraoperative findings were scrutinized. Data on key structures or locations were filled into a data gathering tool. Categorical descriptions were used for surgical findings: "present" or "absent" for location, and "intact" or "eroded" for status of ossicles and critical structures. Radiological readings to describe location and extent of disease were recorded as either "involved" or "uninvolved," while "intact" or "eroded" were used to describe the status of ossicles and critical structures identified. Statistical correlations were computed using Cohen kappa coefficient. Sensitivity, specificity, and predictive values were also computed.

Results: No correlation between radiologic readings and surgical findings were found in terms of location and extent of cholesteatoma ($\kappa < 0$). However, moderate agreement was noted in terms of status of the malleus ($\kappa = .42$, 95% CI, .059 to .781, $p < .05$), substantial agreement noted for the incus status ($\kappa = 0.682$, 95% CI, .267 to .875, $p < .05$), and fair agreement noted for the stapes status ($\kappa = .303$, 95% CI, -.036 to .642, $p > .05$). Slight agreement was also noted in description of facial canal and labyrinth ($\kappa = .01$, 95% CI, -.374 to .394, $p > .05$), while no correlation was noted for the status of the tegmen ($\kappa = 0$, 95% CI, -.392 to .392, $p < .05$).

Conclusion: Our study shows the unreliability and shortcomings of CT scan readings in our institution in detecting and predicting surgical findings. An institutional policy needs to be considered to ensure that temporal bone CT scans be obtained using techniques that can appropriately describe the status of the middle ear and adjacent structures with better reliability.

Keywords: *cholesteatoma; temporal bone, tomography, x-ray computed, mastoidectomy*

Correspondence: Dr. Chris Robinson D. Laganao
Department of ENT-Head and Neck Surgery
Southern Philippines Medical Center, JICA Building
Bajada, Davao City 8000
Philippines
Phone: +63 916 539 5589 / +63 925 795 7538
Email: chrisdlaganao@gmail.com

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Cholesteatoma is a benign keratinizing mass lined by stratified squamous epithelium in the middle ear cavity.¹ It is associated with bony erosion into neighboring structures and can give rise to intracranial and extracranial complications.² In 2017, the European Academy of Otolaryngology and Neurotology/Japanese Otological Society (EAONO/JOS) Joint Consensus Statements defined the stages of cholesteatoma to achieve a uniform classification on the extent of disease and guide surgical decisions and predict outcomes.^{1,2} The classification however, is based solely on intraoperative findings and does not rely on preoperative imaging studies.¹ This raises questions on the reliability and practicality of preoperative CT scans in accurately predicting intraoperative findings during mastoidectomy.

Critical to the management of cholesteatoma is the definitiveness of diagnostic workups.^{3,4} In particular, CT scans often dictate whether surgery is indicated in problematic and chronically discharging ears.^{5,6} Preoperative CT scans influence the decision for and timing of surgical exploration.⁷ However, although temporal bone CT scans can accurately demonstrate the presence of abnormal tissue in the middle ear, they cannot ascertain whether or not this soft tissue density represents a cholesteatoma.⁸

This study aims to determine the correlation between pre-operative in-house temporal bone CT scan readings and intraoperative findings during mastoidectomy for cholesteatoma in a tertiary government hospital.

METHODS

This review of records was conducted with approval of the Department of Health Cluster Research Ethics Committee and Southern Philippines Medical Center Institutional Review Board. The annual census of the Department of ENT-HNS was reviewed for mastoidectomies performed from January 2018 to December 2019. There were only 22 mastoidectomies for middle ear cholesteatoma in 2018, doubling to 46 in 2019. Of the two-year total of 68 patients, only 27 obtained their preoperative temporal bone CT scans in our institution. Given this number, the adequate sample size needed was 25 to achieve 95% confidence level and 5% margin of error.

All charts of patients who underwent mastoidectomy and had in-house preoperative temporal bone CT scans were considered for inclusion in this study. Charts with incomplete data, missing surgical memoranda, technique, and operative findings, history of craniofacial trauma, and temporal bone neoplasms were excluded. If the official temporal bone CT scan reading was not available in the chart or in the hospital PACS system, the chart was not included in the study. There was no third-party consult with the radiology department in terms of verifying official temporal bone CT interpretations to avoid bias.

The radiographic descriptions of structures concerned were based solely on what was described on the official results available in the chart.

In-house temporal bone CT scans were all performed using a Hitachi 128 slice high resolution CT scanner (Scenaria SE 128, Hitachi Ltd., Japan) with 5mm cuts. Comparison of findings was based on the template utilized by the Department of Radiology in reading temporal bone CT scans which include the following parameters: extent and location of cholesteatoma (mastoid or tympanic), status of ossicles, facial canal, labyrinth, and tegmen.

Once charts were retrieved from the medical records section, the surgical memoranda containing intraoperative findings were scrutinized. Data on the key structures or location were filled into a data gathering tool. Categorical descriptions were used for surgical findings. Descriptions for location were either "present" or "absent." The terms "intact" or "eroded" were used to describe the status of ossicles and critical structures. Radiological findings to describe the location and extent of the disease were either "involved" or "uninvolved," while the terms "intact" or "eroded" were used to describe the status of ossicles and critical structures identified.

Cohen's Kappa coefficients were used to determine agreement of surgical findings and radiological readings. A result of less than 0 (<0) meant no agreement. Kappa values between 0.00 and 0.20 meant slight agreement; 0.21 and 0.40 meant fair agreement; 0.41 and 0.60 meant moderate agreement; 0.61 and 0.80 meant substantial agreement, and 0.81 and 1.00 meant almost perfect agreement. Sensitivity, specificity, and predictive values were also computed.

RESULTS

Of the 27 charts that met inclusion criteria, two charts were further excluded for malignancy recorded in the official histopathology report. Thus, only 25 charts were finally included in this study.

Table 1 shows the correlations between surgical findings and radiologic readings in terms of location and extent of cholesteatoma (e.g., attic, attico-antral, tympanic, and tympanomastoid). Cohen's Kappa coefficient statistical test results suggested that CT scan readings did not correlate with surgical findings. Negative values were noted in terms of accurately predicting the extent of the disease for the attic ($\kappa = -.5$, 95% CI, -1.194 to .194, $p > .05$), attico-antral ($\kappa = -.5$, 95% CI, -1.235 to .235, $p > .05$), tympanic areas ($\kappa = -.33$, 95% CI, -.893 to .173, $p > .05$), and a low correlation was noted in the tympanomastoid area ($\kappa = .695$, 95% CI, -.382 to .740, $p > .05$).

Table 2 shows the correlations between surgical findings and radiologic readings regarding the status of ossicles (intact or eroded). There was moderate agreement in the determination of the status of the malleus ($\kappa = .42$, 95% CI, .059 to .781, $p < .05$). In seven cases,

the malleus was radiologically intact and confirmed intraoperatively intact. Eleven cases that were read as abnormal on CT scan were also confirmed to be eroded during surgery. However, there were seven cases where the radiologic readings were contradicted by intraoperative findings. In these seven cases, three had radiologic readings of erosion but were surgically intact while four had normal radiologic readings but were found to be eroded intraoperatively. For the incus, substantial agreement ($\kappa = 0.682, 95\% \text{ CI}, .267 \text{ to } .875, p < .05$) was noted between radiologic readings and surgical findings. A total of 21 cases were consistently intact (10) or eroded (11). Three cases were noted to be radiologically abnormal but surgically intact, while one case noted to be radiologically intact was found to be eroded during surgery. For the stapes, there was fair agreement ($\kappa = .303, 95\% \text{ CI}, -.036 \text{ to } .642, p > .05$) between radiologic readings and surgical findings. Nine cases considered intact radiologically were confirmed intact surgically, while seven cases read as abnormal radiologically were confirmed eroded surgically. There was also disagreement in the case of nine patients (two cases found radiologically intact but found to be eroded intraoperatively, and seven cases read as abnormal on CT scans but surgically intact).

Table 3 shows the correlations between surgical findings and radiologic readings in terms of the status of critical structures such as the facial canal, labyrinth, and tegmen. Generally, surgical findings agreed only slightly with the radiological readings (between 0.00 and 0.20). The facial canal was noted to be radiologically intact in 21 cases, but only 16 of those were confirmed intraoperatively. Among the four cases in which the facial canal was diagnosed as radiologically abnormal, three were intact surgically. Only one case was found to be abnormal both radiologically and intraoperatively. Similar values were seen for the status of the labyrinth and tegmen. The computed correlation coefficient for the status of facial canal and labyrinth was $\kappa = .01$ (95% CI, $-.374 \text{ to } .394, p > .05$) suggesting slight agreement; and $\kappa = 0$ (95% CI, $-.392 \text{ to } .392, p < .05$) for the tegmen, suggesting no agreement.

Table 4 shows the sensitivity, specificity, positive and negative predictive values of radiological readings for surgical findings. The sensitivity of in-house temporal bone CT scan readings was only 50% in the determination of minimal/limited disease (attic and tympanic), and 0% in the case of attico-antral involvement but were 86.62% sensitive in detecting tympanomastoid involvement. However, in-house temporal bone CT scan readings had 0% specificity in terms of location. In terms of erosion of ossicles, the sensitivity of in-hospital temporal bone CT scan readings was consistently above 70%. Specificity slightly varied from 70% for the malleus, 72.73% for the incus, and 56.25% for stapes erosion. The positive predictive value for malleus and incus was 78.57%

but only 50% for predicting stapes erosion. The negative predictive values were consistently above 60%. In-house temporal bone CT scan readings were not very sensitive in terms of identifying abnormalities in

Table 1. Correlation of surgical and radiologic findings in terms of location and extent of cholesteatoma (attic, attico-antral, tympanic, tympanomastoid) among patients admitted for mastoid surgery (N=25).

Surgical Finding	Radiological findings		Kappa Coefficient	Interpretation	CI (95%, $\alpha=0.05$)			
	Involved	Uninvolved			Lower limit	Upper limit	p value	
Attic	Present	1	1	-5	No agreement	- 1.194	0.194	.134
	Absent	1	0					
Attico-antral	Present	0	2	-5	No agreement	- 1.235	0.235	.248
	Absent	1	1					
Tympanic	Present	2	2	-.36	No agreement	- 0.893	0.173	.361
	Absent	1	0					
Tympanomastoid	Present	11	2	0.179	No to low agreement	- 0.382	0.740	.473
	Absent	2	1					

Table 2. Correlation of surgical and radiologic findings in terms of status of ossicles (intact or eroded) among patients admitted for mastoid surgery (N=25).

Surgical Finding	Radiological findings		Kappa Coefficient	Interpretation	CI (95%, $\alpha=0.05$)			
	Intact	Abnormal			Lower limit	Upper limit	p value	
Malleus	Intact	7	3	0.42	moderate agreement	0.059	0.781	.032
	Eroded	4	11					
Incus	Intact	10	3	0.571	substantial agreement	0.267	0.875	.002
	Eroded	1	11					
Stapes	Intact	9	7	0.303	fair agreement	- 0.036	0.642	.100
	Eroded	2	7					

Table 3. Correlation of surgical and radiologic findings in terms of status of critical structures (facial canal, labyrinth, tegmen) among patients admitted for mastoid surgery (N=25).

Surgical Finding	Radiological findings		Kappa Coefficient	Interpretation	CI (95%, $\alpha=0.05$)			
	Intact	Abnormal			Lower limit	Upper limit	p value	
Facial canal	Intact	16	3	.01	slight agreement	-0.374	0.394	.959
	Eroded	5	1					
Labyrinth	Intact	16	3	.01	slight agreement	-0.374	0.394	.959
	Eroded	5	1					
Tegmen	Intact	16	4	0	no agreement	-0.392	0.392	.000
	Eroded	4	1					



Table 4. Sensitivity, specificity, positive and negative predictive values of radiological findings on surgical findings among patients admitted for mastoid surgery (N=25).

CT Findings	Sensitivity (%)	Specificity (%)	Positive Predictive Value (%)	Negative Predictive Value (%)
Attic involvement	50.00	0.00	50.00	0.00
Attico-Antral	0.00	50.00	0.00	33.33
Tympanic	50.00	0.00	66.67	0.00
Tympanomastoid	84.62	0.00	100.00	0.00
Malleus erosion	73.33	70.00	78.57	63.64
Incus erosion	78.57	72.73	78.57	72.73
Stapes erosion	77.78	56.25	50.00	81.82
Facial canal erosion	16.67	84.21	25.00	76.19
Labyrinth fistula	16.67	84.21	25.00	76.19
Tegmen erosion	20.00	80.00	20.00	80.00

other critical structures such as facial canal erosion, labyrinthine fistula, or tegmen erosion, with sensitivity below 20%, although specificity was at least 80%. These readings also had low positive predictive value around 20% only but high negative predictive value above 70%.

DISCUSSION

Computed Tomography scans are highly regarded guides to plan the surgical approach, prognosticate cases, and most importantly, advise patients on the possible outcomes of surgery and manage expectations.^{9,10} We aimed to determine the correlation between preoperative in-house temporal bone CT scan readings and intraoperative findings during mastoidectomy for cholesteatoma but did not find any correlation between radiologic readings and surgical findings in terms of location and extent of cholesteatoma.

The identification of the location and extent of cholesteatoma is important to plan the surgical approach. However, one major disadvantage of CT is that it can overestimate the disease as it cannot distinguish definitively between cholesteatoma and granulation tissue.¹¹ Cholesteatoma has a tendency to reside in hidden areas such as the sinus tympani and anterior epitympanum.¹³ Preoperative knowledge of disease extent and information on degree of mastoid pneumatization seen in CT scans therefore facilitates planning of the surgical approach, whether to keep the canal wall up or take it down.

There is a wide range of agreeability of CT scans in terms of identifying the location and extent of cholesteatoma, with correlation coefficients ranging from moderate to substantial ($\kappa = 0.41$ to 0.80).^{9,12,14} Even so, most authors agree that CT can only detect presence or absence of soft tissue density in the middle ear, and cannot distinguish the type of tissue (cholesteatoma vs granulation).⁹ Our study found no agreement between radiologic interpretations and surgical findings ($\kappa < 0$). Sensitivity was only 50% in detecting cholesteatoma in the attic and tympanic cavity, while specificity was 0%. Furthermore, the

sensitivity of CT findings in detecting cholesteatoma surgically in the tympanomastoid was 84.62% but remained nonspecific (0%). The positive predictive value (defined as the ability of the test, in this case CT scan readings, to correctly predict the presence of disease) was also equivocal in this study (50%).

The condition of the ossicles is well depicted in a high-resolution CT scans.^{10,12} The literature reports that preoperative temporal bone CT scans have a moderate to substantial correlation with intraoperative findings in terms of detecting ossicular pathology (0.41 to 0.80).^{9,12,14} In our study, moderate statistical agreement was found between preoperative temporal bone CT scan readings and intraoperative findings during mastoidectomy in terms of determining the status of the malleus, substantial agreement for the status of the incus, and fair agreement for the status of the stapes. Similarly, preoperative CT scans had a sensitivity and specificity of 90.32% and 81.82% in detecting erosion in the ossicles.¹⁴ In our study, sensitivity to detect erosion in the malleus, incus, and stapes was above 70% at least. Specificity, on the other hand, fell to 56.25% in ruling out erosion of stapes, while remaining above 70% for the two other ossicles. Most common alterations found include medial displacement of the chain, fusion and hardening of the chain, and erosion of the long process of the incus. Similar to other studies, the status of the stapes was the most difficult to assess radiologically.¹⁵

Facial canal dehiscence is a fairly common finding in 55% of temporal bones and usually occurs in a focal area in the tympanic portion of the fallopian canal.¹³ High-resolution CT scan findings are usually straightforward.^{2,13} However, in overly diseased middle ears the soft tissue density may abut on the fallopian canal and cause problems in assessing its integrity.¹⁴ A problem with partial volume averaging artifact is evident as the fallopian canal can be so thin even in a non-pathological ear as to appear dehiscent on CT scan. This may explain poor radiological correlations with surgical findings.¹³ In one study, the sensitivity of CT scans was only 66.67%.¹⁵ In our study, the sensitivity and specificity in detecting facial canal erosion was 16.67% and 84.21%, respectively. This means that less than one-fifth of facial canal erosions noted intraoperatively were seen in the preoperative CT scan, and that normal radiologic findings translated to normal surgical findings in at least 80% of the time. Similar to the results of other studies, there was only slight agreement between preoperative CT scan readings and surgical findings in terms of determining facial canal status in our study.^{11,13,14}

The most commonly affected structure in cases of middle ear cholesteatoma is the lateral semicircular canal.^{10,14} A prospective study consisting of 100 cases of cholesteatoma revealed that their CT scan images only showed thinning of the bone over the lateral semicircular canal with no obvious fistulization. And yet, careful dissection of the

cholesteatoma matrix over the dome of the lateral semicircular canal revealed a tiny bony canal fistula.⁹ This explains how minute fistula may be missed radiographically in some patients. In one study, the sensitivity and specificity in detecting labyrinthine fistula was 80% and 100%.¹⁶ In our study, the sensitivity and specificity were 16.67% and 84.21%, respectively. With that, the positive predictive value of preoperative CT scans was pegged at 25.00% which means that only a quarter of the true labyrinthine fistulas can be detected by CT scans. The negative predictive value of temporal bone CT scans in our institution was 76.19% which means that there is a good chance that intact semicircular canals noted radiologically are also intact intraoperatively. Only 16 out of 21 cases that were reported intact radiologically were indeed intact during the surgery. Overall, preoperative radiological reading and surgical findings had only slight agreement at 0.01. In contrast, other studies reveal a correlation coefficient as high as 0.712 (substantial agreement).^{13,14,15}

Assessing access by examining the tegmen tympani and dural height can alter the surgical method and plan. The surgeon may opt for a canal wall up or canal wall down mastoidectomy depending on that information. Tegmen erosion is well seen on coronal imaging, but again misinterpretations may result from volume averaging effects. In one study, the correlation of preoperative CT scan and surgical finding on the status of the tegmen was 0.712 (substantial agreement).¹³ In our study, the computed correlation coefficient was only 0 (no to slight agreement). Likewise, positive and negative predictive values of preoperative CT were 20% and 80%, respectively. This means that CT scan readings in our study were unable to detect the presence of the disease even if it was actually present.

Our study has several limitations, and several confounding variables were present. Interrater reliability may have affected our study findings since the temporal bone CT scan images were interpreted by different radiology consultants. In the same way, surgeries were performed by different surgeons, accounting for variations in their descriptions of intraoperative findings. Our use of Cohen's Kappa coefficient was deemed the most appropriate tool to ensure that interrater reliability was taken into consideration. Correlation coefficient values vary among institutions depending largely on the availability of the high-resolution CT machine, personnel experience, and lag time, among others.¹³

Moreover, the size of each CT imaging cuts done in the institution is significantly larger than the ones done in other studies (5 mm vs. 1mm).¹³⁻¹⁶ In turn, the effect of partial volume averaging will cause difficulties in terms of determining status of minute bony structures in the middle ear. Thus, it is highly recommended to employ thinner cuts (1mm) in every temporal bone CT scan performed. Furthermore, it is also recommended to develop a unified system of describing

radiological readings unique to the temporal bone CT scan to prevent missing out describing structures significant to the surgeon in terms of planning the surgery and advising the patient.

In conclusion, our study shows the unreliability and shortcomings of CT scan readings in our institution in detecting and predicting surgical findings. An institutional policy needs to be considered to ensure that temporal bone CT scans be obtained using techniques that can appropriately describe the status of the middle ear and adjacent structures with better reliability.

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