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Variation among pre-surgical CT assessments of Chronic Otitis Media

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Abstract. *Variation among pre-surgical CT assessments of Chronic Otitis Media. Objective*: To investigate the reliability of preoperative computed tomography (CT) in patients with chronic otitis media (COM) as assessed by otologist-ENT surgeons, compared with surgical findings and respective radiological assessments, and to identify areas of the middle ear that are difficult to evaluate reliably with preoperative CT.
Materials and methods: Fifty patients with COM underwent preoperative temporal bone CT reported by a qualified radiologist. Each operating surgeon completed a standardized questionnaire regarding the status of 10 middle-ear structures after the operation. Two otologists blindly reviewed the scans. AC_1-statistics between the radiology/otology report and the intra-operative findings were calculated.
Results: In the attic, malleus-incus complex, tympanic cavity, and round window niche, the otologists' assessments of CT scans corresponded better to intra-operative findings than did the respective radiology report. In the lateral semicircular canal and sigmoid sinus, the otologists' assessments also outperformed those of the radiologists in cases of erosion. Radiological assessments outperformed those of otologists in only one of 10 studied areas: confirmation of an unexposed dura in the tegmen area. The scutum and oval window represent difficult areas for which to obtain a reliable preoperative CT scan report.
Conclusion: Otologists' assessments regarding the pre-surgical status of the temporal bone in COM appear more reliable than those of radiologists. This finding has serious implications in current clinical practice, and should be considered when designing strategies for Radiology Head & Neck training. The inherent limitations of CT may necessitate modifications to imaging and operating strategies.

Introduction

High-resolution computed tomography (CT) represents a significant advance in temporal bone imaging, allowing sectional images of significant detail to be obtained. Therefore, CT has been established as the standard of imaging for the preoperative depiction of the temporal bone.[1,2] However, its exact role in the preoperative assessment of patients with chronic otitis media (COM) remains unclear.[3,4] The value of CT in these patients is believed to be the opportunity for a detailed description of the erosive effects, or the obliteration of important elements of the middle ear and the mastoid cavity, such as the ossicular chain, attic area, walls of the tympanic cavity, and mastoid air-cell complex.[5] If the CT scan is considered reliable, it may influence otological decision-making, clinical management, and planning of the surgical approach in each particular case; it may also allow the surgeon to weigh the expected benefits against the potential risks.

However, we observed in a previous study that the preoperative radiology report was unable to provide a reliable assessment of the status of the scutum, attic, oval window, and round window (when obliterated) in patients with COM. Hence, these areas were regarded at high risk for errors in the radiology report.[6] In addition, there was only fair agreement between the radiology report and the intra-operative condition of the tympanic cavity and the malleus-incus complex; even the well acknowledged "ice cream cone" appearance of the latter was associated with a negative predictive value of no more than 27.8%.[6]

We elected to investigate whether the results would differ if the preoperative CT scans were reported by otologist-ENT surgeons rather than radiologists. The same CT scans were blindly assigned to two otologists.

The study had two primary endpoints. The first endpoint was the identification of areas of the middle ear for which it is difficult to obtain reliable reports during the preoperative CT scan in patients

with COM. Inaccurate reporting of these areas by radiologists and otologists may be considered an inherent limitation of the imaging technique. The second endpoint was the identification of areas of the middle ear that could be more reliably assessed by otologists or radiologists. Therefore, inaccurate radiology reporting in these areas should not be considered an inherent limitation of the imaging technique.

Materials and methods

A double-blinded retrospective study incorporating a single-blinded prospective study[6] was conducted at a tertiary university hospital. The study included 50 patients with unilateral COM (50 ears). CT scans had been initially reported by a radiologist, who was blinded with regard to the affected ear. Relevant and/or particular comments in the radiology report were noted, and lack of comments was considered suggestive of normal CT findings. The present study compared assessments of the same CT scans by two otologists with surgical findings (the gold standard).

CT scans were performed in axial and coronal planes in a bone window setting. The patients did not have any active ear discharge for at least 4 weeks prior to scanning. Their population comprised of 24 males and 26 females. The mean age was 47.3 years (age range 16-84 years).

Immediately after each operation, the operating surgeon had completed a standardized questionnaire regarding the intra-operative status of 10 middle ear structures. The examined structures included the scutum, the attic, the malleus-incus complex, the tympanic cavity, the oval window, the round window, the mastoid air-cells, the lateral semicircular canal (LSCC), the tegmen tympani and dura, and the sigmoid sinus. The intra-operative condition of the scutum, malleus-incus complex, LSCC, tegmen tympani, and sigmoid sinus was described as either normal or eroded. An exposed dura was also noted if the area of the tegmen tympani was eroded. The respective conditions of the attic and the tympanic cavity was reported by the surgeon as either normal or occupied by soft tissue. The oval and round windows were described as either normal or obliterated by soft tissue. Finally, the intra-operative status of the mastoid air cells was reported as either normal, sclerotic, or occupied by soft tissue.

Soft tissue obliteration was usually caused by granulomas or cholesteatomas. Although many of the ears studied had a cholesteatoma, this distinction was considered irrelevant or even misleading, as the key issue in the present paper was the correct identification of soft tissue (irrespective of its nature) in CT scans. Distinguishing cholesteatoma from other soft tissue is beyond the capacity of CT, and the target of new MRI techniques.[7]

After the operation, and again blinded to any information about the affected ear or the surgical findings, each CT scan was individually reported by the two otologist-ENT surgeons. The otologists completed the same standardized questionnaire as the operating surgeon. None of the otologists knew any details of the patients' history, management, radiological details, or surgical details. The inter-observer agreement between the otologists was determined and the surgical findings were subsequently compared with their reports.

The statistical analysis used AC_1 statistics; the respective interpretation is summarized in Table 1. Confidence intervals for AC_1 were also estimated. Statistical significance was accepted at $p<0.05$.

Results

The results of the present study are summarized in Tables 2 and 3.

With regard to the scutum, the otologists' assessment of the preoperative scans demonstrated a statistically significant agreement with the surgical findings (Tables 2, 4, 5). Although this agreement was rather poor ($AC_1 = 0.28$), it was still reliable ($p<0.05$). In contrast, the radiology report was completely unreliable in predicting the status of the scutum ($AC_1 = 0.01$, $p>0.05$). The inter-observer agreement between the otologists was very strong ($AC_1 = 0.84$, $p<0.0001$).

These findings became more notable when the attic area was assessed. The agreement of the otologists with the surgical findings was moderately strong ($AC_1 = 0.77$ and 0.80), especially in cases of attic erosion (Tables 2, 4, 5). This agreement again scored much higher than the respective radiology report, which had been totally unreliable in predicting the status of the attic ($AC_1 = 0.13$, $p>0.05$). The inter-observer agreement between the otologists once more proved very strong, especially in cases of an abnormal image ($AC_1 = 0.82$, $p<0.0001$).

In contrast, the oval window represented an area of relative inconsistency between the otologists' pre-surgical assessments and the intra-operative findings. The inter-observer agreement between the otologists was moderately strong ($AC_1 = 0.70$, $p < 0.0001$); however, the respective agreement with the surgical findings was poor but statistically significant for otologist A ($AC_1 = 0.36$, $p = 0.002$) and unreliable for otologist B ($AC_1 = 0.21$, $p > 0.05$). The agreement only seemed to be fair when the oval window was obliterated. In addition, there was no agreement between the radiology report and the otologists' opinions; this disagreement was primarily attributed to the inability of radiologists to detect an obliterated oval window. The overall agreement between the radiology report and the surgical findings was, once more, not statistically significant ($p > 0.05$).

The round window niche appears to represent the area of least agreement for the otologists. Their inter-observer agreement was only fair ($AC_1 = 0.48$, $p < 0.0001$), both for the depiction of obliteration and for normal-appearing round windows. Their respective agreement with the intra-operative findings was fair overall and statistically significant (Tables 2, 4, 5). The agreement between the radiology report and the surgical findings was poor ($AC_1 = 0.29$), but statistically significant ($p = 0.005$).

We observed slightly more promising results regarding the preoperative radiology report for the malleus-incus complex ($AC_1 = 0.42$, $p < 0.001$) and the tympanic cavity ($AC_1 = 0.46$, $p < 0.0001$); the overall agreement with the surgical findings was fair. Again, the situation was better when the otologists assessed the CT scans (moderately strong agreement), and appeared more reliable when the complex was eroded or the tympanic cavity was affected by the disease. The inter-observer agreement between the otologists was also moderately or very strong, especially in cases of an eroded malleus-incus complex ($AC_1 = 0.80$, $p < 0.0001$) or an affected tympanic cavity ($AC_1 = 0.83$, $p < 0.0001$).

The areas of the sigmoid sinus, LSCC, and mastoid air cells appeared easier for either the otologists or the radiologists to assess correctly; all demonstrated a moderately strong or very strong agreement with the surgical findings. The same also applied to the inter-observer agreement between the two otologists. When compared to the radiology report, the otologists still agreed moderately strongly in cases of an intact LSCC or sigmoid sinus; however, there was no reliable agreement in the presence of erosion ($p > 0.05$). Regarding the mastoid air cells, the agreement between the otologists and the radiologists remained very strong, irrespective of the presence or absence of pathology.

The tegmen area was the only area where radiologists outperformed otologists ($AC_1 = 0.68$, vs. 0.61 and 0.59, respectively), although all reports exhibited reliable and statistically significant agreement with the surgical findings. The inter-observer agreement between the otologists was again very strong ($AC_1 = 0.91$, $p < 0.0001$). However, the agreement between the otologists and the radiologists was reliable mostly in cases of a delineated tegmen. No reliable correlation was observed when the tegmen had been breached ($p > 0.05$).

Discussion

The present study highlighted the difficulties in reliably reporting the status of 10 different middle ear structures in patients with COM, using CT scan protocols routinely employed in clinical practice. It is beyond the scope of this article to comment on those protocols, the specific models of scanners used, or the professional competence of the reporting radiologists, whose intensive efforts to promote appropriate patient management are well acknowledged.

Cohen's kappa statistic has long been used to quantify the level of agreement between two raters, and had been used in previous imaging studies.[4,8,9] However, the limitations of kappa-type measures, i.e. their sensitivity to raters' classification probabilities (marginal probabilities),[10] necessitated the introduction of an alternative statistic, the AC_1-statistic. The AC_1-statistic is a robust measure of agreement, more consistent with the percentage of agreement between raters in all situations, and was therefore used to assess the reliability of CT imaging in our patient group.

In four of the assessed structures (attic, malleus-incus complex, tympanic cavity, and round window niche) the otologists' pre-surgical assessments of the CT scans corresponded better to the intra-operative findings than did the preoperative radiology report. Otologists also performed better than radiologists in two other structures (LSCC and sigmoid sinus) in cases of erosion, although their performance was similar when these structures were not eroded. Only in the tegmen area were the

Table 1

Strength of agreement in AC_1-statistics[11]

AC_1 value	*Strength of agreement*
>0.8	Very strong
0.6-0.8	Moderately strong
0.3-0.5	Fair
<0.3	Poor

Table 2

Cumulative data regarding agreement between the surgical findings and otologist A, otologist B, and the radiology report

Middle ear structure	*Otologist A vs. Surgeon*			*Otologist B vs. Surgeon*			*Radiologist vs. Surgeon*		
	Agreement (%)	*AC_1 value*	*p value*	*Agreement (%)*	*AC_1 value*	*p value*	*Agreement (%)*	*AC_1 value*	*p value*
Scutum	64	0.28	0.018	64	0.28	0.020	46	0.01	0.472
Attic	82	0.77	0.000	84	0.80	0.000	50	0.13	0.156
Malleus-incus	84	0.79	0.000	76	0.63	0.000	66	0.42	0.000
Tympanic cavity	86	0.70	0.000	72	0.57	0.000	66	0.46	0.000
Oval window	66	0.36	0.002	58	0.21	0.053	34	-0.21	0.955
Round window	74	0.48	0.000	76	0.52	0.000	54	0.29	0.005
Mastoid air-cells	92	0.93	0.000	90	0.89	0.000	88	0.93	0.000
LSCC	86	0.78	0.000	88	0.76	0.000	76	0.68	0.000
Tegmen tympani	72	0.59	0.000	74	0.61	0.000	76	0.68	0.000
Sigmoid sinus	100	1.00	0.000	94	0.93	0.000	96	0.96	0.000

radiologists in a better position to confirm its delineation, which may in turn suggest that the dura has not been exposed. It is possible that the more frequent exposure of the radiologists to brain images may have augmented their better perception of what appears normal in this area. Hence, the accuracy of the preoperative CT scan report in the aforementioned areas appears to be closely related to the relative experience of the reporting physician, and inaccurate reporting cannot be considered an inherent limitation of the imaging technique.

By contrast, the scutum and the oval window represent areas for which it is difficult to obtain a reliable reported during the preoperative CT scan in patients with COM. Therefore, inaccurate reporting in these regions may be considered an inherent limitation of the imaging technique.

Another important finding of the present study was that even though the reporting radiologists were by definition considered as the imaging standard for reliably reporting the status of the middle ear, they actually performed worse than the otologists in six of the 10 examined middle ear structures, and especially the structures that are important to surgical planning (i.e., the attic). It should be noted that the otologists possessed a different training background (USA vs. UK), belonged to different schools of surgical perspective (primarily open vs. intact canal surgical technique), and were not certified to report CT scans of the temporal bone. This alarming result must be taken into account in designing strategies for Radiology Head & Neck training, as the radiologists are actually the doctors that are certified to report CT scans of the

Table 3

Inter-observer agreement between otologists' interpretations of preoperative CT scans from patients with chronic otitis media

Middle ear structure	*Agreement (n) (N)*	*Agreement (ab) (N)*	*Non-agreement (n + ab) (N)*	*Agreement (%)*	*AC_1 value*	*p value*
Scutum	25	21	4	92	0.84	0.000
Attic	3	40	7	86	0.82	0.000
Malleus-incus	6	34	10	80	0.70	0.000
Tympanic cavity	6	38	6	88	0.83	0.000
Oval window	15	27	8	84	0.70	0.000
Round window	19	18	13	74	0.48	0.000
Mastoid air-cells	1	45	4	92	0.91	0.000
LSCC	36	9	5	90	0.85	0.000
Tegmen tympani	38	9	3	94	0.91	0.000
Sigmoid sinus	45	2	3	94	0.93	0.000

n: normal findings; ab: abnormal findings; N: number of cases.

middle ear. However, they must also be properly qualified to report reliably on this complex region.

Hence, the fact that each reporting radiologist in the present study may not have been dedicated to head and neck imaging does not actually represent a weakness of the study, but rather an additional strong point. Indeed, when an ear surgeon receives a radiology report regarding the status of the middle ear, that surgeon is not always in a position to know whether the reporting radiologist is dedicated to head and neck imaging. The key issue is that the radiologist is the one appointed by his/her department to provide a report about a specific patient. Therefore, not only is it in a patient's best interest that the surgeon knows or suspects which areas of the middle ear are more difficult to assess preoperatively or more likely to be incorrectly described in the preoperative radiology report, but this may actually represent a prerequisite in order for patients to be provided with realistic expectations and informed consent to be obtained. Hopefully, the results of the present study and other similar studies may affect current clinical practice to the extent that temporal bone CT scans are assessed by dedicated oto-radiologists. Whether this change in clinical practice will substantially improve the respectiv radiology reports remains to be seen.

Looking at more specific details, an interesting finding of the present study, with regard to the sigmoid sinus, was that the strength of the agreement between the radiology report and the surgical findings relied on the radiologists' ability to accurately recognize an unexposed sigmoid sinus. The respective specificity reached an absolute 100%, according to the results of the present study. However, the sensitivity of the radiology report did not exceed 33%. By contrast, otologists appear to be more able to detect an eroded sigmoid sinus, in addition to an unexposed one. Indeed, perfect agreement ($AC_1 = 1$) was observed between the surgeon and the imaging report of one of the two otologists regarding the 50 operated ears. In addition, very strong agreement between the radiology report and the otologists' opinions was only observed in cases of non-erosion of the sinus.

The agreement between the CT scan report and the surgical findings with regard to the status of the LSCC appears to relate differently to its condition, depending on the reporting party. Hence, the moderately strong agreement between the radiology report and the surgical findings in the area of the LSCC was primarily observed in the absence of any erosion. By contrast, the respective agreement between the otologists and the surgeon appeared

Table 4

Cumulative data regarding agreement between otologist A and surgical findings

Middle ear structure	*Agreement (n) (N)*	*Agreement (ab) (N)*	*Non-agreement (n) (N)*	*Non-agreement (ab) (N)*	*Agreement (%)*	*AC_I value*	*p value*
Scutum	14	18	6	12	64	0.28	0.018
Attic	2	39	3	6	82	0.77	0.000
Malleus-incus	3	39	4	4	84	0.79	0.000
Tympanic cavity	6	37	7	3	86	0.70	0.000
Oval window	10	23	8	9	66	0.36	0.002
Round window	20	17	8	5	74	0.48	0.000
Mastoid air-cells	2	44	1	3	92	0.93	0.000
LSCC	35	8	4	3	86	0.78	0.000
Tegmen tympani	33	3	7	7	72	0.59	0.000
Sigmoid sinus	47	3	0	0	100	1.00	0.000

n: normal findings; ab: abnormal findings; N: number of cases.

Table 5

Cumulative data regarding agreement between otologist B and surgical findings

Middle ear structure	*Agreement (n) (N)*	*Agreement (ab) (N)*	*Non-agreement (n) (N)*	*Non-agreement (ab) (N)*	*Agreement (%)*	*AC_I value*	*p value*
Scutum	15	17	5	13	64	0.28	0.020
Attic	1	41	4	4	84	0.80	0.000
Malleus-incus	5	33	2	10	76	0.63	0.000
Tympanic cavity	4	32	9	5	72	0.57	0.000
Oval window	8	21	10	11	58	0.21	0.053
Round window	21	17	7	5	76	0.52	0.000
Mastoid air-cells	0	45	3	2	90	0.89	0.000
LSCC	37	7	3	3	88	0.76	0.000
Tegmen tympani	33	4	7	6	74	0.61	0.000
Sigmoid sinus	45	2	2	1	94	0.93	0.000

n: normal findings; ab: abnormal findings; N: number of cases.

more uniform. Their agreement was also reliable when the LSCC had been eroded. The implication is that according to the results of the present study, radiologists appear unable to detect the fistulization of the LSCC, which is considered an absolute indication for surgical intervention in cases of COM.

However, although it may appear surprising at first that radiologists were unable to confirm that the scutum had been eroded, the respective agreement between the otologists and the surgeon was also poor, even though they performed better than the radiologists. Therefore, the preoperative CT scan appears to have limited reliability when determining the condition of the scutum.

Furthermore, radiologists appear unable to confirm reliably that the attic area is normal, even though a radiologist can more easily detect preoperative erosion. However, the fact that the agreement between the otologists' opinions and the respective intra-operative findings is moderately strong indicates that radiologists and otologists interpret the same images differently.

The results of the present study appear to warrant special attention regarding the round window niche. It was initially noted that radiologists did not appear to be in a position to comment reliably on its status. Radiologists had missed 22 ears with round window involvement, and had wrongly identified one. Therefore, the sensitivity of the preoperative radiology report for the round window niche was 0%. The respective specificity was 96.4%, which may be attributed to the fact that the reporting radiologist almost never identifies a round window as being obliterated by soft tissue. By contrast, both otologists correctly identified 17 ears with round window involvement. However, it should be mentioned that this region represents the area of least radiological agreement for the reporting otologists (Table 5). Their inter-observer agreement was only fair ($AC_1 = 0.48$, $p = 0.000$), both for the depiction of erosion and for normal-appearing round windows. This finding highlights the great difficulty associated with pre-surgical assessment of the round window, and the fact that surgeons should be prepared for surprises in this area.

Finally, the oval window also represents an area of inconsistency between the preoperative report by the radiologist and the intra-operative findings. In fact, the preoperative radiology report successfully identified only one ear with oval window involvement, and had failed to discern 31 others. The respective agreement between the surgical findings and the otologists' reports was also poor; however, preoperative erosion was easier to detect. There was also poor agreement between the radiology report and the otologists' opinions, which appears to be primarily caused by the radiologists' inability to detect an obliterated oval window. Hence, the preoperative CT scan appears unable to determine *per se* that the oval window is free of disease; however, the experience of the reporting physician plays a central role in identifying its erosion. This observation has crucial implications, as the condition of the oval window and the stapes supra-structure is very important for the reconstruction of the hearing mechanism and the resulting postoperative hearing thresholds in patients with COM.

However, it is very likely that radiologists are unfamiliar with the importance of oval and round windows for otological surgical practice, and may therefore omit them from their reports. This possibility further highlights the need for closer and better cooperation between otologists and radiologists (particular persons in each hospital, and the respective colleges, as well).

Conclusion

High-resolution CT represents the standard imaging technique for preoperative depiction of the temporal bone, and can play an important role in preoperative assessment and surgical planning for patients with COM. The present study clearly demonstrated that otologists appear more reliable in assessing the pre-surgical status of the temporal bone in cases of COM than radiologists. This finding has serious implications in current clinical practice, and should be taken into account when designing strategies for Radiology Head & Neck training. Finally, the inherent limitations of CT involve at least the scutum and the oval window, and may necessitate related modifications to imaging and surgical strategies.

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