

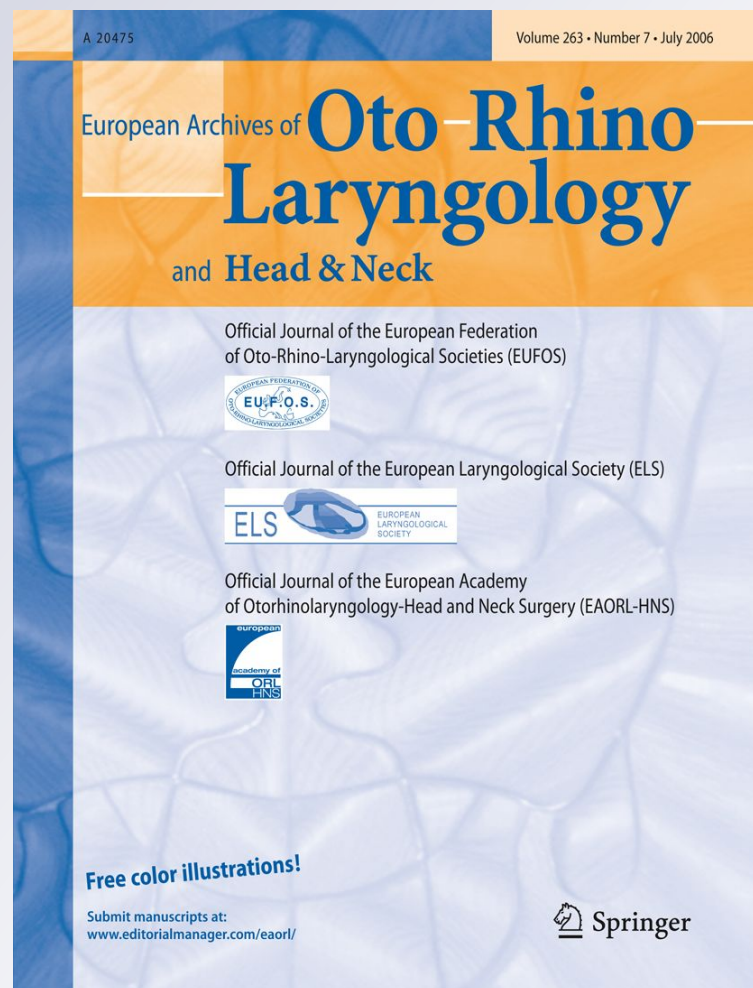
CT scan versus surgery: how reliable is the preoperative radiological assessment in patients with chronic otitis media?

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CT scan versus surgery: how reliable is the preoperative radiological assessment in patients with chronic otitis media?

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Abstract The objective of the study was to evaluate the accuracy of the preoperative radiological assessment regarding 10 different middle ear structures in patients with chronic otitis media (COM). The setting of the prospective study was in a Tertiary university hospital. Fifty patients scheduled for a primary operation for COM. All patients underwent preoperative temporal bone high-resolution CT-scan (HRCT). AC_1 -statistics between the radiological report and the intra-operative findings were calculated. There was no correlation between the radiological assessment and the surgical findings in the scutum, attic area, and oval window. There was a poor or fair agreement on the condition of the malleus–incus complex, the status of the tympanic cavity, and the round window. There was a moderately strong agreement regarding the status of the lateral semicircular canal (LSCC) and tegmen tympani. This

agreement was primarily observed, when no erosion/exposure was present in the LSCC or the dura. There was a very strong agreement in the mastoid air-cell complex and the sigmoid sinus, especially when the former was abnormal and the latter had no pathology. There are significant difficulties in radiological imaging for reliably assessing the middle ear in patients with chronic otitis media, using HRCT. The preoperative CT scan generally underestimates the actual pathology found by the surgeon in certain middle ear areas. The decision for surgical intervention should not be based on the radiological interpretation of certain middle ear structures, and ENT surgeons should be prepared to encounter conditions which are not reported by the radiologist preoperatively, and modify the operating strategy accordingly. EBM level: 2c.

Keywords CT scan · Radiology · Imaging · Surgery · Temporal · Chronic otitis media · Cholesteatoma

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Introduction

Radiological assessment in chronic otitis media has always been considered very important by otologists, not only in the context of their decision-making, but also for planning their surgical approach and methods, and weighing the expected benefits against the potential risks. The development of high-resolution computed tomography (CT) represented a significant advance in temporal bone imaging, allowing sectional images of significant detail to be obtained [1].

Hence, CT was gradually established as the imaging of choice for the preoperative depiction of the temporal bone [2]. Its value in patients with chronic otitis media lies in the opportunity for a detailed assessment of erosion or

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 the mastoid air-cell complex. If such a preoperative assessment is reliable, it can influence the clinical management and affect the surgical technique in each particular case.

There are, however, drawbacks associated with CT imaging of the middle ear. Due to anisometric voxels, which are inherent to the multi-slice CT technique, the appearance of the structures depends very much on the scan plane. Important anatomical structures in the temporal bone can remain below resolution limit, and appear either blurred (due to the partial-volume effect), or not seen at all [3]. In addition, it is often difficult to appreciate the complex, multi-spatial orientation of these structures, contained as they are within a compact region, or their interrelationships [4]. Although the addition of more and thinner sections to the detector subsystem, combined with the change from a parallel-beam to a cone-beam reconstruction, may decrease scanning time and concomitantly increase spatial resolution [3, 5], the increasing number of slices that are necessary when image reconstruction is performed, may make the process of mentally integrating these slices into a prospective 3D model quite challenging. Moreover, the presence of chronic infection can magnify the inherent drawbacks of CT imaging in the temporal bone. Finally, the experience of the radiologist may play an important role in interpreting the radiological findings of a temporal bone CT scan.

As a consequence, the exact value of HR CT in the preoperative assessment of patients with chronic otitis media still remains controversial [6, 7].

The aim of the present study was to compare the preoperative radiological assessment of the most important anatomical structures of the middle ear in patients with chronic otitis media, with the intra-operative findings (gold standard).

Materials and methods

A prospective study was conducted at a Tertiary university hospital in patients who were scheduled to undergo a primary operation for unilateral chronic otitis media. Fifty patients were included in the study: 24 of them were males and 26 were females. The mean age was 47.3 years (age range 16–84 years).

Following Departmental guidelines for patients scheduled for ear surgery, a CT scan of the temporal bone was performed preoperatively in axial and coronal planes.

The operating surgeon completed a standardized questionnaire regarding the intra-operative status of 10 middle ear structures, immediately after the operation. The examined structures included the scutum, attic, malleus–incus complex, tympanic cavity, oval window, round window, mastoid air-cells, lateral semicircular canal (LSCC), tegmen tympani and dura, and the sigmoid sinus.

The intra-operative condition of the scutum, malleus–incus complex, LSCC, tegmen tympani, and the sigmoid sinus was either described as normal or as eroded. An exposed dura was also noted, if the area of the tegmen tympani was eroded.

The respective condition of the attic and the tympanic cavity was either reported by the surgeon as normal, or occupied by soft tissue.

The oval and round windows were either described as normal, or obliterated by soft tissue.

Finally, the intra-operative status of the mastoid air-cells was either reported as normal, sclerotic, or occupied by soft tissue.

The respective intra-operative findings, taken as the gold standard, were compared with the preoperative radiological assessment (Table 1). Relevant and/or particular comments in the radiology report were noted, and lack of comments was considered as suggestive of normal CT findings.

The statistical analysis used the AC_1 -coefficient of agreement. The interpretation of AC_1 statistics is summa-

Table 1 Cumulative data of the agreement between radiology report and gold standard

Middle ear structure	Agreement (n) (N)	Agreement (ab) (N)	Non-agreement (n) (N)	Non-agreement (ab) (N)	Agreement (%)
Scutum	19	4	1	26	46
Attic	3	22	2	23	50
Malleus–incus	6	27	1	16	66
Tympanic cavity	4	29	9	8	66
Oval window	16	1	2	31	34
Round window	27	0	1	22	54
Mastoid air-cells	0	44	3	3	88
LSCC	37	1	2	10	76
Tegmen tympani	37	1	3	9	76
Sigmoid sinus	47	1	0	2	96

n normal findings, *ab* abnormal findings, *N* number of cases

Table 2 Strength of agreement in AC_1 -statistics

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

rized in Table 2. Confidence intervals for AC_1 were also calculated. Statistical significance was accepted at a level of 0.05.

Ethical considerations

The research protocol was submitted, and received ethical approval by the Ethics Committee of the University of Athens, prior to commencing data collection. No extra imaging, in addition to the specified by the respective Departmental guidelines, was performed on any of the participants, due to their participation in the study. Participants were asked to sign a consent form before being enrolled in the study.

Results

With regard to the scutum, the preoperative radiological assessment did not have any significant correlation with the surgical findings ($AC_1 = 0.01$, $p > 0.05$), suggesting that the CT-scan is totally unreliable in assessing this particular area of the middle ear.

In the attic area, there was again no overall correlation between the radiology report and the surgical findings ($AC_1 = 0.13$, $p > 0.05$), although an abnormal (occupied by soft tissue) attic was detected preoperatively more easily—fair agreement with surgery ($AC_1 = 0.37$, $p < 0.021$).

Slightly more promising results were found in the malleus–incus complex, where the agreement between the preoperative radiological assessment and the surgical findings was overall fair ($AC_1 = 0.42$, $p < 0.001$), becoming stronger ($AC_1 = 0.59$, $p < 0.001$) when the ossicles were eroded, but disappearing in cases of an intact ossicular chain.

Similar results were found in the tympanic cavity—an overall fair agreement ($AC_1 = 0.46$, $p = 0.000$) became moderately strong in cases of occupied cavities ($AC_1 = 0.64$, $p < 0.001$). In other words, the preoperative CT scan demonstrated a satisfying sensitivity in detecting an involved tympanic cavity (78.4%), whereas its specificity was very low (30.8%).

With regard to obliteration of the oval window by soft tissue, there was no significant correlation between the preoperative radiology and the surgical findings, suggesting

that the CT scan is totally unreliable in preoperatively assessing this area ($AC_1 = -0.21$, $p > 0.05$).

The situation was slightly better in the round window niche. An overall poor agreement was found between the radiology report and the surgical findings ($AC_1 = 0.29$, $p = 0.005$), which became fair in normal cases ($AC_1 = 0.54$, $p < 0.001$). The reason seemed to be due to the rather disappointing fact that the preoperative CT scan could not discern an obliterated round window niche. Not a single affected ear (out of 22 with surgically confirmed pathological round windows) was correctly identified by the radiologist, thus limiting the respective sensitivity to 0%.

In contrast, a very strong agreement between the radiological assessment and the intra-operative findings was seen in the mastoid air-cells ($AC_1 = 0.93$, $p < 0.001$). This seemed especially true when the mastoid complex was abnormal (sclerotic mastoids included) ($AC_1 = 0.97$, $p < 0.001$), whereas there was no statistically significant correlation in the few normal cases. Hence, the preoperative CT scan seemed sensitive enough to detect abnormalities in the mastoid air-cells (93.6%).

As far as the lateral semicircular canal (LSCC) was concerned, a moderately strong agreement was found between the preoperative CT scan and the surgical findings ($AC_1 = 0.68$, $p < 0.001$). This was mainly attributed to the strong agreement in the absence of any erosion ($AC_1 = 0.82$, $p < 0.001$).

Similar findings were also encountered in the tegmen area. The agreement of the preoperative radiological report with the surgical findings was overall moderately strong ($AC_1 = 0.68$, $p < 0.001$), but basically observed, when the dura was not exposed (strong agreement, $AC_1 = 0.82$, $p < 0.001$).

Finally, the radiological assessment agreed very strongly with the intra-operative condition of the sigmoid sinus ($AC_1 = 0.96$, $p < 0.001$). This was mainly due to the almost perfect agreement in cases of normal sigmoids ($AC_1 = 0.98$, $p < 0.001$). In the three cases with pathology in the sigmoid sinus, the radiologist had preoperatively detected only one. Hence, the preoperative CT scan demonstrated an impressive 100% specificity in the sigmoid sinus, whereas the respective sensitivity was relatively low (33%).

A summary of the observed sensitivity and specificity in the 10 middle ear structures which were studied is illustrated in Table 3.

Discussion

The present study evaluated the accuracy of the preoperative radiological assessment regarding 10 different middle ear structures in patients with chronic otitis media, by comparing the preoperative radiology report with the

Table 3 Accuracy of the preoperative CT scan regarding the status of 10 middle ear structures in patients with chronic otitis media

Depicted structure	Accuracy of preoperative CT scan	
	Sensitivity (%)	Specificity (%)
Scutum	13.33	95
Attic	48.88	60
Malleus–incus	62.8	85.7
Tympanic cavity	78.4	30.8
Oval window	62.8	85.7
Round window	0	96.4
Mastoid air-cells	93.6	0 ^a
LSCC	0.5	94.87
Tegmen tympani	0.5	94.87
Sigmoid sinus	33 ^b	100

^a There were only 3 normal cases

^b There were only 3 abnormal cases

intra-operative findings (gold standard). 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 [2, 7, 8]. However, the limitations of kappa-type measures, i.e. their sensitivity to raters' classification probabilities (marginal probabilities) [9], necessitated the introduction of an alternative statistic, the AC₁-statistic, which is more consistent with the percentage of agreement between the raters in all the situations [10]. It is the first time that this robust measure of agreement has been used to assess the reliability of preoperative CT imaging in patients with chronic otitis media.

The present study was designed as blinded between the radiologist and the surgeon. Hence, the reporting radiologist was not aware of the surgical findings. The radiologist did not complete the standardized questionnaire that was given to the operating surgeon, but was allowed to report the radiological findings of the temporal bones unbiased. This brought the study closer to everyday clinical practice, where the lack of comments is considered as suggestive of normal findings, and is consequently interpreted as such, by the requesting clinicians.

The design of this prospective study has taken into account the fact that the reporting radiologist may not have been dedicated to otology. This, however, may actually represent one of the strengths of the present study. Indeed, the reality of everyday ENT practice in many countries is that ear surgeons do not have the opportunity to choose their radiologists, and usually receive a radiological assessment without necessarily knowing the experience, or background, of each reporting radiologist. The key issue is that all the radiologists in the present study were the ones appointed by their department to provide a report regarding each specific patient with chronic otitis media. Therefore, it

is in a patient's best interest that the surgeon knows or suspects before the operation, which areas of the middle ear are more difficult to be assessed preoperatively, or more likely to be incorrectly described in the radiological report.

The results of the present study suggest that the preoperative HR CT scan is generally very unreliable regarding specific important structures of the middle ear in patients with chronic otitis media, overall underestimating the actual pathology found by the surgeon.

A strong agreement between radiology and surgery was indeed only found in four of the 10 structures, which were studied. With regard to the remaining six middle ear areas, a fair agreement was found in two, a poor agreement in one, and no agreement in three areas. Such observations obviously represent more than academic dilemmas. Can an ENT surgeon plan an atticotomy and obtain informed consent, based on a preoperative CT scan which is unable to assess the status of the attic? On the other hand, can medico-legal issues arise, if the surgeon considers a CT scan of the temporal bones non-obligatory before middle ear surgery, due to its limited combination of sensitivity and specificity regarding a number of middle ear structures?

Preoperative CT scans of the temporal bones are not routinely performed before middle ear surgery in all otological centres. However, all the pros and cons, as discussed in the present study, should be taken into account before departmental policies are implemented, or a decision on a specific case is taken.

It seems that the scutum, attic, oval window, and the round window niche represent middle ear structures that the radiologist is not able to assess reliably. Hence, these areas should be considered as weak, or of high risk for errors in the radiology report. It is, indeed, rather alarming that not a single affected ear (out of 22 with surgically confirmed pathological round windows) was correctly identified by the radiologist, thus limiting the respective sensitivity to 0%.

On the other hand, the mastoid air-cell complex and sigmoid sinus are areas much easier assessed by the radiologists. This seems to be especially true when the former is abnormal, and the latter is found exposed during the operation. Hence, the sensitivity of the preoperative CT scan in detecting abnormalities in the mastoid air-cells is very high (93.7%), whereas its specificity in recognizing an unexposed sigmoid sinus reaches an absolute 100%, according to the results of the present study. However, the results were rather disappointing in the few cases with pathology in the sigmoid sinus; only one out of three surgically confirmed cases was preoperatively detected by the radiologist.

In addition, a strong agreement between the CT scan assessment and the surgical findings was found in the LSCC and the tegmen tympani. This agreement seems to relate to the condition of the aforementioned structures,

when no erosion is present in the LSCC, and when the dura is not found exposed during surgery. These results do not seem to agree with the results of Jackler et al. [11], who reported that the CT scan gives the erroneous impression of LSCC fistulization and tegmen tympani erosion, due to volume averaging of these structures with adjacent soft tissue. Their study, however, had used older generation CT scanners, which may have been the reason for this discrepancy. In addition, Gerami et al. reported a weak and insignificant agreement between the preoperative radiological images and the intra-operative findings in patients with chronic otitis media, in cases of tegmen tympani erosion and LSCC fistulas [8]. O'Reilly et al. [7] suggested that the preoperative CT scan is moderately sensitive to the presence of LSCC fistulas and less sensitive to the presence of small areas of exposed dura. Only Alzoubi et al. [2] reported that all of their cases with genuine tegmen tympani breach had been preoperatively reported correctly, and that the preoperative CT scan is accurate in revealing inner ear fistulas. However, most related studies, including the present one, had very few cases with LSCC fistulas or dura exposure, in order for robust conclusions to be drawn. Moreover, the size of the fistula, or the dura exposure in these cases, may significantly affect their detection, when imaging is performed.

Finally, there seems to be a fair agreement between the preoperative radiological report and the intra-operative condition of the malleus–incus complex. It was very interesting to note that the well-acknowledged “ice-cream cone” appearance of the malleus–incus complex carries a negative predictive value of not more than 27.8%, according to the results of the present study. This means in effect that its depiction is not a guarantee that the complex has not been eroded, although the latter can be somehow expected, as chronic otitis media usually erodes the long process of the incus, which is not normally seen on a CT scan.

The present study highlighted the difficulties in reliably reporting the status of 10 different middle ear structures, in patients with chronic suppurative otitis media, using CT scan protocols routinely employed in clinical practice. It was 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.

It is possible that the accuracy of preoperative radiological diagnosis can also improve with the use of appropriate MRI protocols. Indeed, delayed contrast-enhanced T₁-weighted, or diffusion-weighted MR imaging were proven helpful in discriminating between cholesteatomatous and non-cholesteatomatous tissue in the middle ear, with positive and negative predictive values as high as 100% [12–15]. These techniques, however, do not always seem to be

able to detect related complications of chronic suppurative otitis media on individual middle ear structures, and have not yet been widely applied in the clinical practice.

Conclusion

HR CT scan represents the imaging of choice for the preoperative depiction of the temporal bone in patients with chronic suppurative otitis media. The obtained images, however, need to be interpreted cautiously, in view of its limitations and numerous pitfalls. It is essential that ENT surgeons are always aware of these limitations, and pay special attention to the fact that CT scans tend to underestimate the actual pathology, which is intra-operatively found by the surgeon in certain middle ear areas. Hence, the decision for surgical intervention should not be based on the findings of the CT scan, at least in certain middle ear structures, and ENT surgeons should be prepared to encounter conditions which are not reported by the radiologist preoperatively, and modify the operating strategy accordingly.

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Conflict of interest None.

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