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ORIGINAL ARTICLE

Comparative computed tomography study on the tympanosquamous suture in attic cholesteatoma vs healthy ears

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KEYWORDS
Anterior tympanosquamous suture;
attic cholesteatoma aetiopathogenesis;
computed tomography

Abstract
Introduction and objectives: When performing surgery on ears with cholesteatoma, we observed a higher prominence of the anterior edge of the tympanosquamous suture (TSS). The aim was to find out whether these surgical findings corresponded to a specific morphology of the tympanosquamous suture (TSS) in cholesteatomas.
Material and methods: A retrospective analysis was carried out using preoperative computed tomography (CT) of the TSS in patients undergoing surgery for cholesteatoma in the period between January 2006 and December 2008. Patients older than 18 years who had not been previously operated were included, with a CT performed at the hospital and with a histology that proved cholesteatoma (n=31). The findings of the TSS from these 31 cases were compared with those of 30 healthy ears. The healthy group included 20 cases of unilateral cholesteatoma (20 healthy/31 cholesteatomas) and a control group of 10 healthy patients studied for cochlear implants (n=10). Measurements of the distance in mm. were made selecting two points A and B of the TSS (A being the furthest point to the edge of the suture and B the nearest). The CT cuts were selected according to the greatest and smallest separation of the TSS.
Results: Comparing the maximum and minimum distance of the TSS in points A and B in all the ears, according to pathological state (healthy ears vs cholesteatoma ears), we detected a reduced minimal distance in A (P=.036) and B (P=.014) in the healthy ears with respect to the cholesteatoma ears. No statistically significant differences were found in maximum distances A and B (P>.05).
Conclusions: This study provides objective data on a lesser closure of the TSS in cases of cholesteatoma vs healthy ears. We correlate this finding with the aetiopathogenesis of attic cholesteatoma.

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PALABRAS CLAVE
Sutura timpanoescamosa anterior;
Etiopatogenia del colesteatoma atical;
Tomografía computarizada

Estudio comparativo mediante tomografía computarizada de la morfología de la sutura timpanoescamosa entre colesteatoma atical y oídos sanos

Resumen
Introducción y objetivos: Habíamos observado, al intervenir oídos con colesteatoma, una mayor procidencia del extremo anterior de la sutura timpanoescamosa (STE). Queríamos averiguar si estos hallazgos correspondían a una especial morfología de la STE en los colesteatomas.
Material y métodos: Realizamos un estudio retrospectivo, mediante tomografía computarizada (TC) preoperatoria, de la STE de pacientes intervenidos por colesteatoma entre enero de 2006 y diciembre de 2008. Se incluyó a pacientes mayores de 18 años, no intervenidos anteriormente, con TC realizada en el propio hospital e histología demostrativa de colesteatoma (n = 31). Comparamos los hallazgos de la STE de estos 31 casos con los de 30 oídos sanos. El grupo sano incluyó 20 casos con colesteatoma unilateral (20 sanos/31 colesteatomas) y un grupo sano control estudiado con motivo de implante coclear (n = 10). Se realizaron mediciones de la distancia en mm considerando dos puntos A y B de la STE (A era el mas distal y B, el mas proximal al extremo de la sutura). Seleccionamos los cortes de TC correspondientes a la máxima y la mínima separación de la STE.
Resultados: Comparando las distancias máxima y mínima de la STE en los puntos A y B de todos los oídos, según estado patológico (sanos frente a colesteatoma), detectamos una menor distancia mínima A ($p = 0{,}036$) y mínima B ($p = 0{,}014$) en los oídos sanos respecto a los patológicos; no encontramos diferencias estadísticamente significativas de las distancias máximas A y B ($p > 0{,}05$).
Conclusiones: Este estudio aporta datos objetivos sobre un menor cierre de la STE en los casos de colesteatoma frente a oídos sanos. Relacionamos este hallazgo con la etiopatogenia del colesteatoma atical.

Introduction

Years ago, we published a study[1] based on observations made during surgery for chronic otitis. It drew our attention that ears affected by cholesteatoma presented a higher prolapse of the tympanic bone end, at the union of both structures of the tympanosquamous suture (TSS). We did not find this feature in ears without cholesteatoma lesions. We wanted to find an objective method to study TSS morphology.

With modern computed tomography (CT) equipment, which allowed us to perform anatomical reconstructions of areas that were previously inaccessible, we were able to carry out a study of the TSS. We sought the areas of maximum and minimum separation between the two structures (tympanic bone and pars squamosa); these distances are measured in mm. Two study groups were established for comparisons, one consisting of ears with cholesteatoma (n=31) and another one consisting of healthy ears (n=30).

We observed that there were statistically significant differences of a reduced closure of the TSS in ears with cholesteatoma, in relation to healthy ears. We relate the finding of a greater opening of the TSS in cases of cholesteatoma with the formation of cholesteatoma. These findings are consistent with the theory of “papillary growth” of the epidermis into the underlying connective tissue advocated by Nager[2] and Habermann.[3]

The interest of the study resides in providing further objective information about the factors contributing to the occurrence of attic cholesteatoma. We must recall the anatomy of the attic area to assess, in this context, the importance of a difference in the usual TSS morphology.

The tympanic membrane presents two areas with very different structures: the pars tensa and the pars flaccida. The pars tensa has three distinct layers: the outer layer with keratin epithelium, the middle or fibrous layer and the internal or mucosal; the middle layer is well structured, architecturally, with collagen fibres distributed circularly and radially and constituting an effective barrier isolating the keratin epithelial layer from the inner layer of mucosal epithelium.[4] The pars flaccida or tympanic area, corresponding to the arc of the external auditory canal (EAC) between both ends of the tympanic bone, lacks the structured middle layer and consists of loose connective tissue. Its structure is identical to that of the skin in this part of the EAC of which it is a continuation.

It is important to bear in mind that the skin is thicker in the upper area of the EAC, in the part between the TSS and the tympanomastoid, and that it adherence to sutures, a fact described in studies done on surgical anatomy of the temporal bone.[5] The skin covering the EAC in the area corresponding to the tympanic bone is thinner.

It is in the front part of the Rivinus incisure that the anterior end of the TSS described in various studies[6-8] can be found, and it is this prolapse that we observed and described in a previous study, constituting the *“primum movens”* of the current study. We have found no published work relating to radiological studies of the anatomy of the TSS or relating to the role that their anatomical variants may play in the genesis of cholesteatoma. This gives, in our view, a value of originality to this contribution.

Materials and methods

Design: study of a series of clinical cases.

Study population: all patients attending the otolaryngology service at our hospital for cholesteatoma surgery (unilateral or bilateral) from January 2006 to December 2008 who underwent preoperative CT at this same centre. The Inclusion criteria were: 1) adults (18 years or older) with cholesteatoma (unilateral or bilateral); 2) undergoing cholesteatoma surgery for the first time in the otolaryngology service of our hospital; 3) preoperative CT scan done in the same centre; 4) histological study confirming the cholesteatoma.

Variables studied and their definitions

From the preoperative CT images, we made measurements of the distance between points A (most distal point from the anterior end of the tympanic bone) and B (most proximal point) in the areas of maximum and minimum separation (measured in mm) between the tympanic bone and the squamous part of the temporal bone according to the radiological technique specified below.

Radiological technique

- Scan Parameters: the studies reviewed were carried out with a General Electric multidetector CT model LightSpeed 16. The images were acquired through a helix of the temporal bone with a collimation of 0.625 mmx16 mm and a reconstruction interval of 0.625 mm. Studies were performed using 140 kV and 300 mAs and with Bone+filter.
- Post-processing of images: the images were reconstructed and treated with Advantage Workstation 4.2 (General Electric) by the radiology technician and the specialist in otolaryngology. The coronal plane of the petrosal was obtained from the axial plane and through this the sagittal plane with respect to the EAC. The measurements were made from the resulting images of this plane (Figures 1-3).

Sources of information

Data were extracted from hospital medical records and the archive of CT images corresponding to the patients in the study. The otolaryngology specialist and the neuroradiologist technician measured and reviewed all scans together.

Statistical analysis

We performed a descriptive bivariate analysis differentiated according to the unit of analysis considered: each ear, according to whether it was healthy or there was cholesteatoma; or patient, for which only those with unilateral cholesteatoma were considered.

Considering each ear as the unit of analysis, a descriptive analysis of measures of central tendency (median) and dispersion (interquartile interval [IQR]) was carried out in accordance with a non-normal distribution (Kolmogorov-Smirnov test, $P<.05$), and bivariate distribution, comparing averages for distance A (maximum and minimum) and B (maximum and minimum) using the Mann-Whitney nonparametric U test. A bivariate analysis was also performed on the paired data using the Student's t-test for paired data or the Wilcoxon test according to the distribution of the variables.

A value of $P<.05$ was considered as statistically significant, and the statistical package used was SPSS 12.0 (Chicago, USA).

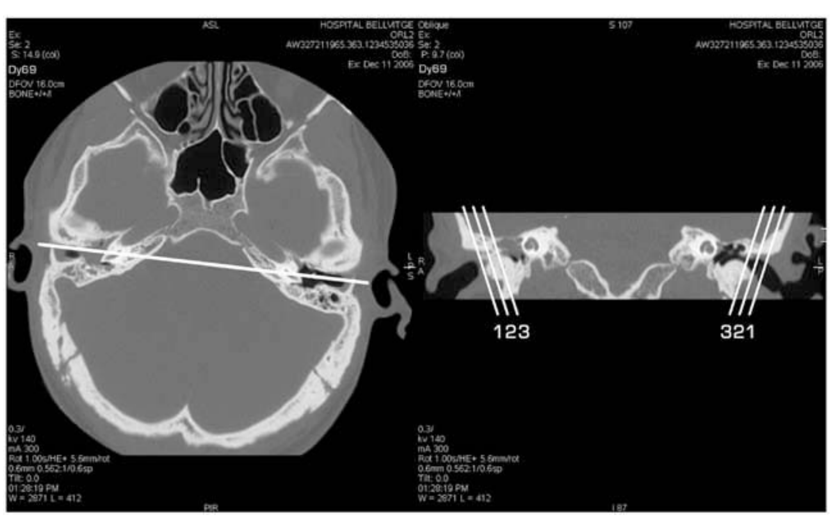

Figure 1 Cut planes at the level of the external auditory canal to study different areas of the tympanosquamous suture.

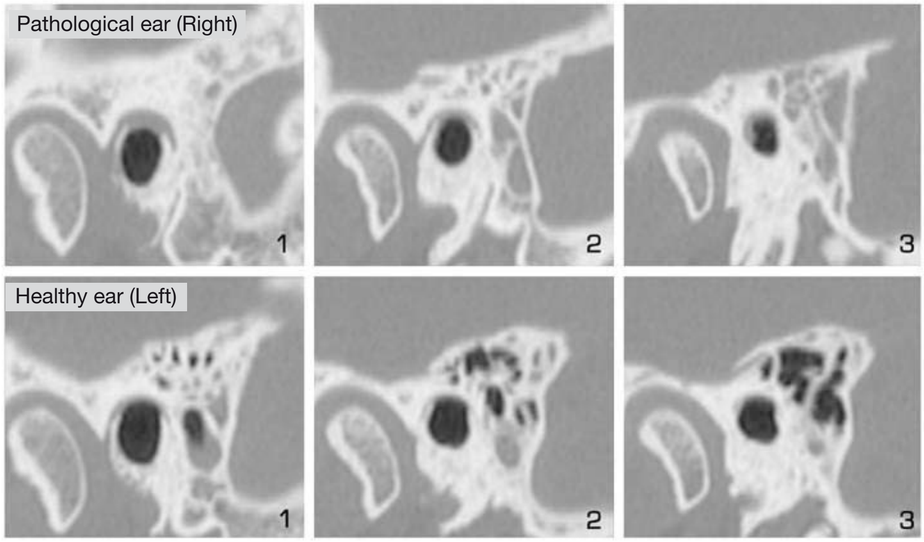

Figure 2 Measurement of the minimum distance between the tympanic bone and the temporal scale. An increase in the side with cholesteatoma in relation to the healthy side can be observed.

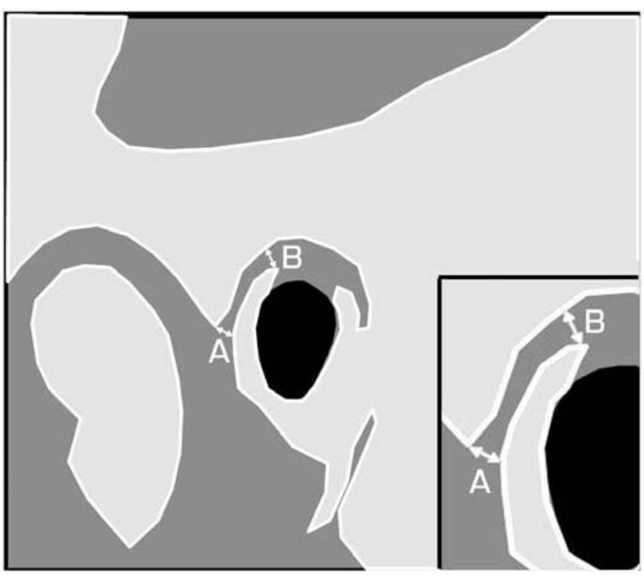

Figure 3 Points A and B in which the measurement was made of the maximum and minimum distances between the tympanic bone and the scale in the tympanosquamous suture. A is the distal part of the anterior end of the tympanic bone and B, the proximal.

Results

Description of the total sample

Of the 31 cases included, all of them met the predetermined criteria: they were intervened for the first time due to attic cholesteatoma at the otolaryngology service of our hospital. Of these, 13% (n=4) presented bilateral cholesteatoma; 20% (n = 6), unilateral cholesteatoma, but with contralateral ear characteristics that could not be evaluated, and 3% (n=1) had a healthy ear, but with contralateral ear characteristics that could not be evaluated. Therefore, 20 (64.5%) patients had unilateral cholesteatoma and healthy contralateral ear (not intervened and with no exostosis of the EAC or other otopathy).

Of the 31 cases (62 ears), 53 (82.8%) ears were included in the analysis, which consisted of the measured distances (A and B), and of these 60.4% (n = 32) presented cholesteatoma (60.4%), mainly in the left ear (18; 56.3%). The average maximum A distance was 0.9 (0.5) mm, and the median maximum B distance was 0.9 (0.5) mm; of the minimum A distance, 0 (0.2) mm and of the minimum B distance, 0 (0.6) mm (Table 1).

Comparison of the averages/medians (n=53)

Comparing the maximum and minimum distances between points A and B for all ears, according to the pathological condition (healthy versus cholesteatoma), lower minimum A (P=.036) and minimum B (P=.014) distances were detected in the healthy ears than in the pathological ones. There were no statistically significant differences in the maximum A and B distances (P>.05).

Paired data sample (n=20)

To eliminate possible inter-individual and intra-individual variability of the distances measured for the study, it was considered important to perform a paired sub-analysis to compare data in the same individual (healthy ear versus diseased ear); for this, only those (n=20) with unilateral cholesteatoma were considered (mostly the left, 65%).

Table 1 Measurements of sample distribution (51 ears)

	Total		Normal		Diseased	
Maximum A distance	51 (0)	0.9 ± 0.5	20 (0)	0.967 + 0.098	31 (0)	0.95 ± 0.7
Maximum B distance	51 (0)	0.9 [0.5]	20 (0)	0.8 [0.5]	31 (3)	0.9 [0.6]
Minimum A distance	51 (0)	0 [0.2]	20 (0)	0	31 (0)	0 [0.7]
Minimum B distance	51 (0)	0 [0.6]	20 (0)	0	31 (0)	0 [0.7]

The data express No. (percentage of lost cases); average ± standard deviation according to the Kolmogorov-Smirnov test ($P>.05$); and median [interquartile interval].

Table 2 Sub-analysis of paired data in subjects with unilateral cholesteatoma and healthy contralateral ear (n=20)

	No. of Patients (% losses)		*P*
Healthy maximum A distance	20 (0)	0.96 ± 0.1037	.072
Diseased maximum A distance	20 (0)	1.03 ± 0.11	
Healthy minimum A distance	20 (0)	0	.032[a]
Diseased minimum A distance	18 (10%)	0.2 [0.7]	
Healthy maximum B distance	20 (0)	0.85 [0.6]	.40
Diseased maximum B distance	17 (15%)	0.9 [0.6]	
Healthy minimum B distance	20 (0)	0 [0.7]	.011[a]
Diseased minimum B distance	18 (10%)	0.25 [0.8]	

The data express average + standard deviation, according to the Kolmogorov-Smirnov test ($P>.5$) or median [interquartile interval].
[a]Statistically significant ($P<.05$), according to the Student's t-test for paired data or the Mann-Whitney U test, as appropriate.

In the healthy ears, the average + standard deviation of the maximum A distance was 0.96 + 0.10 mm; and in the diseased, it was 1.03+0.11 mm. There were no statistically significant differences ($P=.072$). In the healthy ears, the average maximum B distance was 0.85 (IQR, 0.6) mm and, in the diseased, it was 0.90 (IQR, 0.6) mm. Again, there were no statistically significant differences ($P=.40$).

Regarding the other minimum distances (A and B), statistically significant differences ($P<.05$) were detected, which were always lower in the healthy ears (Table 2).

Discussion

Following the review of the TSS with CT, we found an increase in the minimum distance between the tympanic bone and the squamous part of the temporal in the ears affected by cholesteatoma with respect to healthy ears. This reduced closure of the TSS makes us think that there is a relationship between this anatomical morphology and the formation of the cholesteatomatous lesion.

The fact of a reduced closure of the suture would justify a larger contact area between the dermis of the upper part of EAC, inserted into the cleft of the TSS, and the epithelium of the Prussak space. In cases of otitis, this means greater contact of the dermis of the external auditory canal with the attic inflammatory tissue (Figure 4).

This finding would be added to the theories of Nager[2] and Habermann[3] on the pathogenesis of cholesteatoma based on the "papillary growth" of the epidermis of the pars flaccida towards the conjunctive tissue of the Prussak space, in the first instance, and subsequent progression towards the rest of the cavities of the middle ear. This invasion takes place following the laws of growth of the epithelia studied by Weiss,[9] whereby epithelium grows in the direction marked by the fibres of the underlying connective tissue (contact guidance system).

There are three distinguishing features coinciding in the attic area that are already well known:

1. Increased thickness of the dermis of the skin of the EAC in the area between the tympanosquamous and tympanomastoid sutures.[4]
2. Anatomical continuity of the skin of the upper wall of the EAC and the pars flaccida of the tympanic membrane, which differs from the pars tensa essentially in the absence of its middle layer or structured fibrous layer.[4,6]

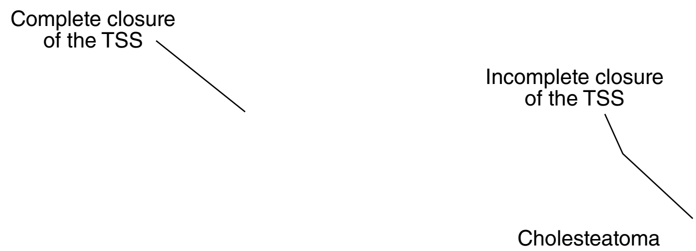

Figure 4 Drawings showing the complete closure of the suture area between the tympanic bone and the temporal squama (healthy ear). An open attic diaphragm can be seen. Incomplete closure of the tympanosquamous suture (TSS). This finding was verified only in ears with cholesteatoma.

3. The existence of the attic diaphragm[4] that, in cases of middle ear inflammation, can isolate and cut aeration from the epitympanic area. This would promote the formation of inflammatory tissue and thus make otitic lesions chronic in the attic region.

Our study introduces a new factor: the existence of an incomplete closure of the suture between the tympanic bone and the squamous portion of the temporal (TSS). TSS morphology presents a statistically significant difference in terms of a deficiency in the seal between the two bony structures that comprise the tympanosquamous suture in ears with cholesteatoma compared with healthy ears. This greater opening of the TSS would explain the increase in contact surface of the dermis of EAC skin with the attic inflammatory tissue in cases of otitis media.

According the studies of Weiss,[9] the epithelium grows in the direction marked by the fibres of the underlying connective tissue. Therefore, it would be this contact area (the dermis of the TSS with attic inflammatory tissue) that would provide the stimulus for growth of the skin into the middle ear. This would reverse the direction of the "lateral migration" of the epidermis that, in normal circumstances, would take place towards the exterior of the EAC.[10] Because the flaking of the keratin in the corneal layer cannot be removed, dermal inflammation gradually takes place, with feedback and "papillary growth" of the deep epidermal layers that invade the dermis. There is also a progression towards adjacent cavities from the area of anatomical contact between dermis and inflammatory tissue of the middle ear.

Conclusions

With this study, we provide objective data regarding anatomical differences in the morphology of TSS in ears with cholesteatoma. We found a greater opening of the distance between both bony structures that make up the TSS in cases of ears with attic cholesteatoma compared with healthy ears.

This difference in morphology affects only the reduced closure of the TSS in cholesteatomas. However, we have not registered an increase in the separation of the TSS, which is similar in both groups (cholesteatoma/healthy). This incomplete closure of the TSS demonstrated radiologically could be considered as the differentiating factor contributing to the formation of cholesteatoma in cases of chronic otitis. The incomplete closure of the TSS justifies an increase in contact area between the dermis of the EAC, which is continuous with the pars flaccida and the attic inflammatory tissue in cases of otitis media.

The observation of this special configuration of the TSS supports the theories basing the genesis of cholesteatoma in the invasion of the middle ear from the skin of the EAC.

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