CORRELATION OF CT ANALYSIS AND AUDIOMETRY IN OTOSCLEROSIS

CORRÉLATION ENTRE LES DONNÉES TOMODENSITOMÉTRIQUES ET LES RÉSULTATS AUDIOMÉTRIQUES DANS L'OTOSPONGIOSE

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ABSTRACT

Aim: The objective of this study is to report our experience by investigating the relationship between the extent of lesions on the CT scan and the preoperative and postoperative audiometric results.
Materials and Methods: We conducted a longitudinal retrospective study including 90 surgically confirmed otosclerosis patients (and 150 ears). All patients underwent hearing evaluation through pure-tone audiometry, and preoperatively, they were examined by temporal bone CT scans.
Results: In pure-tone audiometry, we observed predominantly conductive hearing loss (50%) with an average hearing loss of 35.8 db. On CT scans, signs of otosclerosis were identified in 97.3% of cases, with a predominance of Veillon stage II (41.7%). No correlation was found between the degree of hearing loss and radiological classification. The extent of lesions did not affect postoperative audiometric results ($p > 0.05$).
Conclusion: CT scans provide additional support for positive diagnosis. However, the correlation between radiological lesions and hearing loss, as well as surgical outcomes, was not proven. Thin slice of CT scan may offer valuable insights into the extent of otosclerosis within the inner ear.
Keywords: Otosclerosis, CT scan, Audiometry

RÉSUMÉ

Objectif: Présenter notre expérience en étudiant la relation entre l'étendue des lésions observées au scanner et les résultats audiométriques pré- et post-opératoires.
Matériels et Méthodes: Nous avons mené une étude rétrospective longitudinale incluant 90 patients atteints d'otospongiose confirmée chirurgicalement (soit 150 oreilles). Tous les patients ont bénéficié d'une évaluation auditive par audiométrie tonale et d'un scanner des rochers en préopératoire.
Résultats: L'audiométrie tonale a révélé une surdité de transmission prédominante (50%) avec une perte auditive moyenne de 35,8 dB. Au scanner, des signes d'otospongiose ont été identifiés dans 97,3% des cas, avec une prédominance du stade II de Veillon (41,7%). Aucune corrélation n'a été trouvée entre le degré de perte auditive et la classification radiologique. L'étendue des lésions n'a pas influencé les résultats audiométriques post-opératoires ($p>0,05$).
Conclusion: Le scanner offre des arguments supplémentaires en faveur du diagnostic positif de l'otospongiose. Toutefois, aucune corrélation entre l'extension des lésions radiologiques, la perte auditive et les résultats chirurgicaux n'a été formellement démontrée. Des coupes fines aideraient à détecter l'atteinte de l'oreille interne.
Mots-clés: Otospongiose, Scanner, Audiométrie.

INTRODUCTION:

Otosclerosis is a primary osteodystrophy of the otic capsule, characterized by a combination of osteolysis and osteogenesis phenomena, leading to stapedo-vestibular ankylosis [1]. This condition results in conductive or mixed hearing loss with a normal tympanic membrane. The diagnosis is primarily audiometric, while imaging confirms the presence of otosclerosis foci. Treatment is surgical, with outcomes influenced by various factors, notably the extent of the otosclerotic foci [2]. The aim of this study is to share our experience by analyzing the relationship between the extent of lesions observed on CT scans and the preoperative and postoperative audiometric results.

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MATERIALS AND METHODES

This is a retrospective study involving 90 patients (150 ears), who underwent primary surgery for otosclerosis, at the Military Hospital of Tunis between 2003 and 2021.

Inclusion and Exclusion Criteria:
We included patients who underwent preoperative exploration with temporal bone CT scans and tonal audiometry, where otosclerosis was confirmed intraoperatively. Patients were required to have a minimum follow-up period of 12 months during which they underwent two tonal audiometries: an early evaluation (at 3 months) and a late evaluation (at 12 months). Cases of revision surgery for failed stapes surgery were not included.

Preoperative Imaging:
A high-resolution multi-detector CT scan (with 0.5 mm slices) was systematically performed for all patients preoperatively. The following elements were recorded from the radiology report: Presence or absence of radiological signs suggesting otosclerosis (e.g., thickening of the stapes footplate, hypodensity of the otic capsule). Veillon's classification [2]. Detection of potential endosteal breaches or anatomical variations, such as protrusion of the facial nerve canal, a short process of the incus, or a narrow oval window, as per the Ukkola-Pons method[3].

The surgical report included details about the type of intervention performed on the footplate stapes, the stage of otosclerosis based on Portman's classification, the type of prosthesis used, and any difficulties encountered during the procedure. A double interpretation of the CT scan was conducted in collaboration with radiologists in cases of uncertainty or insufficiently detailed reports.

Audiometric Data Analysis
We applied the 1995 criteria of the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) [4] for our analysis, and the following calculations were performed:

Average Air Conduction (AC): The mean air conduction thresholds at 500, 1000, 2000, and 4000 Hz.

Average Bone Conduction (BC): The mean bone conduction thresholds at 500, 1000, 2000, and 4000 Hz.

Postoperative Residual Rinne (PRR): The difference between the postoperative mean air conduction and the postoperative mean bone conduction.

Cochlear Reserve (CR): The difference between the postoperative mean bone conduction and the preoperative mean bone conduction.

Definition of a Good Postoperative Outcome:
A good postoperative result was defined as achieving a PRR of ≤10 dB at one year, with no signs of labyrinthitis at three months postoperatively (negative CR value).

Statistical Analysis: Data analysis was performed using SPSS software ("Statistical Package for Social Sciences") version 26 and Microsoft Excel 2013. Comparisons of means between independent groups were conducted using Student's t-test. Comparisons of percentages in independent groups were performed using Pearson's chi-square test. When the validity conditions for the chi-square test were not met, Fisher's exact bilateral test was used. For all statistical tests, the significance level was set at 5% (p = 0.05).

RESULTS

The mean age at the time of surgery was 50.3±38 years. There was a clear female predominance, with a sex ratio of 0.5. A family history of otosclerosis was noted in 40% of patients. Unilateral or bilateral hearing loss was the main reason for consultation in all patients, accompanied by tinnitus in 50% of cases. Examination of the external auditory canal and tympanic membrane was normal in all cases. On tonal audiometry, conductive hearing loss was observed in 90 ears, with an average hearing loss of 35.8 dB. In the remaining cases, mixed hearing loss was observed (60 ears). The stapedius reflex was absent in 95% of cases. The analysis of the temporal bone CT scans revealed signs suggestive of otosclerosis in 97.3% of the operated ears (146 ears) (Figure 1,2). In the remaining cases, the CT scan was interpreted as normal (four ears).

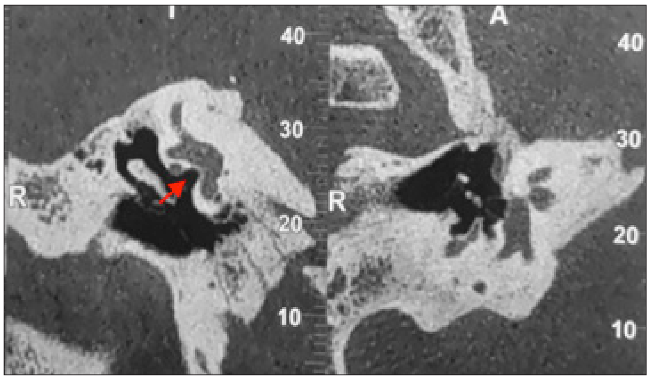

Figure 1: Right Temporal Bone CT scan (Axial Section) revealing 1.5 mm pre-stapedial hypodensity without contact with the cochlear lumen, corresponding to Veillon Type II.

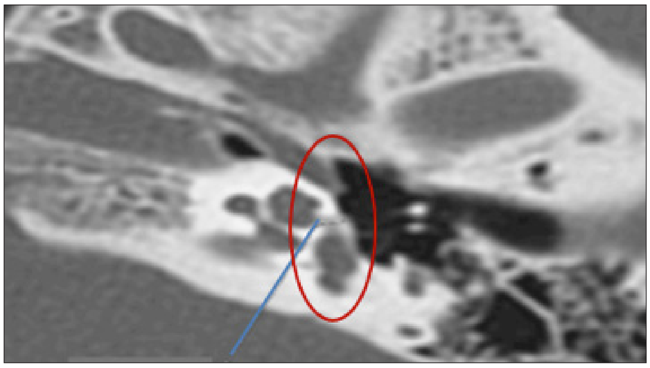

Figure 2: Left Temporal Bone CT scan (Axial Section) showing a pre-stapedial hypodensity that reaches cochlea, suggestive of Veillon Type III otosclerosis.

When radiological signs indicative of otosclerosis were present, Stage II of Veillon's classification was the most frequently observed (Table I).

Table I: Frequency of Different Radiological Stages of Otosclerotic Foci

Type	Percentage (%)	Number (ear)
Ia	17.3	26
Ib	11,3	17
II	43,3	65
III	9,3	14
IVa	9,3	14
IVb	6,7	10

All patients underwent surgery via the endaural approach, with stapedotomy performed using a micro drill and the insertion of a Teflon piston prosthesis (diameter: 0.3 mm to 0.6 mm, length: 4 to 5 mm). Intraoperatively, the following anatomical risk factors were observed:
Protrusion of the facial nerve canal (10 ears)
A narrow oval window, as seen on the preoperative CT scan (5 cases).
A dehiscence of the jugular bulb was discovered incidentally during surgery in one case.
Vertigo was the main complication, reported after 40 surgeries (26.6%). In all cases, vertigo resolved with medical treatment within a few days to several months.
Postoperative audiometric results showed no significant differences between the different stages (p > 0.05). On average, the overall postoperative threshold was 44 dB for AC and 28 dB for BC. The mean postoperative Rinne value was 15.5 dB, with an average variation of 19 dB. The average BC gain was 6 dB. The mean values for air conduction, bone conduction, and postoperative residual Rinne were comparable at both short-term (3 months) and long-term (12 months) follow-up.
Based on the therapeutic outcome criteria established at the start of the study, there was an improvement in success rates at one year. 78.8% of cases (118 ears) had a cochlear reserve (CR) ≤ 0 at both 3 months and 1 year.
Eighty-three percent of operated ears had a postoperative residual Rinne (PRR) < 10 dB at 3 months, and 85% at 1 year.
We found that early stages of Veillon's classification were significantly associated with conductive hearing loss (Table II).
However, no correlation was observed between the degree of hearing loss, preoperative bone conduction thresholds, and the radiological stage of Veillon (Table III).
Radiologically localized involvement (Stage I and II) was associated with better Rinne closure postoperatively, but no statistically significant correlation was found between the extent of otosclerotic foci and postoperative audiometric outcomes (Table III).
The study did not demonstrate a statistically significant relationship between endosteal involvement and postoperative audiometry, although bone conduction gain was lower in the presence of endosteal involvement (Table III).

Table II: Distribution of Different Types of Hearing Loss According to the Radiological Stage of Veillon

Type	Conductive hearing loss	Mixed	P
IA	18	8	<0.05
IB	12	5	<0.05
II	47	18	<0.05
III	9	5	NS
IVA	7	7	NS
IVB	4	6	NS

NS: non-significant

Table III: Effect of extent of Otosclerotic Foci, Endosteal Involvement on Postoperative Audiometric Outcomes:

	Mean Threshold post-operative AC (dB)	Mean Threshold post-operative BC (dB)	post-operative Rinne (dB)	Rinne Variation (dB)	BC Gain (dB)
Stade I / II	43	28	15	23	6
Stade III / IV	45	29	16	15	6
p value	> 0.05	> 0.05	>0.05	>0.05	>0.05
Endosteal Involvement	45	30	20	18	2
No Endosteal Involvement	40	25	15	20	6

Other Findings:
No statistically significant relationship was established between the involvement of the round window, PRR, and CR.

DISCUSSION

Otosclerosis is a primary osteodystrophy of the otic capsule responsible for stapedo-vestibular ankylosis [1,5]. It is the most common of the temporal bone dystrophies [6], and its treatment remains primarily surgical [1]. This is a condition with a female predominance, which may be related to hormonal and/or biochemical factors [7]. It is one of the main etiologies of acquired hearing loss in adults, and audiometry plays a diagnostic role by showing conductive hearing loss or mixed hearing loss with a conductive predominance [8,9].
The hearing loss progresses gradually, with the Rinne becoming smaller, followed by gradual degradation of bone conduction (BC). Computed tomography (CT) is the imaging modality of choice for conductive or mixed hearing loss with a normal tympanum; it is necessary to confirm the diagnosis, but not always required [10,11]. On scanographic images, otosclerosis is characterized by hypodense pathological foci, reflecting the inactive phase (otosclerosis) of the disease. These foci are most often located in the region of the fissula ante fenestram [12,13]. Several scanographic classifications of otosclerotic foci have been proposed, with the Veillon classification being the most widely used [2]:
Type 0: Infra-radiological form, no scanographic anomaly.

Type I a: Isolated thickening of the stapes footplate, hypodense, irregular, with no associated pre-stapedial hypodensity. According to the literature, this stage is associated with mild hearing loss with a predominance of the conductive form (44.8%) and a high rate of sensorineural hearing loss (20.8%). This has been explained by early ossicular blockage[13]. In our series, stage Ia was found in 26 ears, with conductive hearing loss in 18 cases, and no sensorineural hearing loss.

Type I b: Pre-stapedial hypodensity ≤1 mm. No extension to the anterior middle labyrinthine layer. This stage was found in 8% of ears in Veillon's series. The hearing loss was mild to moderate, mixed in 48% of cases, and conductive in 42%. In our series, stage Ib was found in 10 cases, with 6 cases of conductive hearing loss.

Type II: Pre-stapedial hypodensity greater than 1 mm, without contact with the cochlear light.

Type III: Pre-stapedial hypodensity greater than 1 mm, in contact with the cochlear light.

Type IVa: Hypodensity located anterior, below, and inward of the cochlear light. This form indicates certain labyrinthine involvement.

Type IVb: Posterior labyrinthine hypodensity located around the semicircular canals or in contact with the medial part of the vestibule. According to the literature, this stage is associated with mild hearing loss, with a predominance of the conductive form (44.8%) and a high rate of sensorineural hearing loss (20.8%).

For the correlation between CT stages and audiometric findings, according to Veillon's series, which included 1500 patients and 2277 temporal bones, early stages are associated with mild to moderate hearing loss, whereas advanced stages (IVa and IVb) are associated with more severe and earlier hearing loss [1,14]. These findings are supported by the series of Naumann [1] and Gokhan[15]BC. However, Abdel-Ghany[16], De Groot et al.[17], and Saunders et al[18]., when comparing audiograms and CT scans of their otosclerotic patients, did not find a statistically significant correlation between the size of the otosclerotic foci, regardless of the radiological stage, and the audiometric thresholds of BC, air conduction (AC), or Rinne. Our results are consistent with the findings of these latter authors.

The existence of a relationship between endosteal extension and audiometric results is a controversial subject; some studies have found a significant link, such as those by Marx et al.[6]. The latter demonstrated a relationship between the size of endosteal invasion (especially in the basal turn and another turn) and the frequency of sensorineural hearing loss. This phenomenon leads to the release of enzymes into the labyrinthine fluid, causing inflammation and degeneration of intra-cochlear structures, which can lead to total deafness or profound sensorineural hearing loss[9,19]. However, some authors, like Schuknecht and Barber [20], did not observe a correlation between bone conduction and endosteal involvement. Our results align with this study. A detailed study of the round window is an essential element in the radiological and surgical assessment of otosclerosis. Its isolated involvement is rare; it typically results from a diffuse focus originating from the promontory and is often associated with stage IV of Veillon[2]. According to Veillon's classification, the involvement of the round window by otosclerosis is classified into 4 CT stages[2]:

Stage 1: Normal round window.
Stage 2: Focus on the external or internal edges.
Stage 3: Obstruction of the round window.
Stage 4: Ossification of the tympanic ramp.

According to Shin et al.[21], a narrow round window is significantly associated with a decrease in both air and bone conduction thresholds pre- and post-operatively, and with a decrease in the bone conduction gain. In our series, we noted five cases of narrow oval windows, where we observed a decrease in air conduction post-operatively and an increase in the Rinne test post-operatively.

CONCLUSION

The correlation between audiometric results and radiological images in otosclerosis provides a crucial perspective for understanding the pathology. These combined data represent a promising approach for more accurate diagnosis and more targeted interventions, thus paving the way for better management strategies.

Declaration of conflicts of interest:

The authors declare that they have no conflicts of interest.

Ethical considerations: due to the retrospective nature of the study, without experimental intervention the consentment of patients was not necessary but we did respect the anonymity of the patients.

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