

1 **Association between Tegmen Tympani Status and Superior**
2 **Semicircular Canal Pattern.**

3 **Short running head:** Tegmen Tympani Status and SSC Pattern.

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1 INTRODUCTION

2 Superior semicircular canal dehiscence (SSCD) is an audiovestibular
3 structural alteration first described 17 years ago (1). The radiological
4 assessment of SSCD is based on the absence of the bony shell separating
5 the intracranial space and the superior semicircular canal (SSC) in the
6 reconstructions of the Pöschl plane (the plane of each ear's superior
7 semicircular canal). Therefore, the canal's lumen is open to the middle
8 cranial fossa or to the superior petrosal sinus.

9 Currently, SSCD is associated with several pathologies: chronic
10 media otitis (2, 3), temporomandibular joint disruption (4), obesity and
11 sleep apnea (5) and otoliquorrea (6). The first report of tegmen tympani
12 dehiscence (TTD) coincident with SSCD indicated that three of five SSCD
13 cases also showed TTD (7). Joint cases of SSCD and TTD have been
14 reported in isolated cases or very short series (8, 9, 10, 11) and also in large
15 series, showing significant coincidences ranging from 14.2% to 76% (12,
16 13, 14, 15). A common etiology has also been postulated (13).

17 The average thickness of the superior semicircular canal roof is 1.1
18 mm (standard deviation [SD] 0.5mm) (12). On the basis of thickness,
19 tomodensitometric appearance and relationship to temporal cells, we have
20 previously proposed five SSC patterns (16): dehiscence (SSCD),
21 papyraceous or thin (≤ 0.5 mm), normal or classic (0.6-1.7 mm), thick (≥ 1.8
22 mm) and pneumatized (presence of supralabyrinthine cells).

23 The aims of the present work are to detect and quantify the possible
24 tomodensitometric association between tegmen tympani (TT) status and the
25 different superior semicircular canal patterns and to study the possible
26 effects of sex and age on this association.

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30 **MATERIAL AND METHODS**

31 This work was performed between September 2007 and March 2008
32 in three tertiary Spanish Hospitals: Basurto and Cruces Hospitals (Bilbao,
33 Spain) and General Hospital of the Defense (Zaragoza, Spain). The study
34 was approved by the ethics committees of each center according to the
35 guidelines of the Helsinki Declaration of 1964. All patients were informed
36 about the study and signed the relevant consent forms. They were recruited
37 from among those subjected to computerized axial tomography (CAT scan)
38 of the temporal bone due to hypoacusia, facial palsy, vertigo, tinnitus and
39 other single or combined symptoms. CAT scans were reviewed by senior
40 radiologists who had more than 10 years of experience in neuroradiology.

41 We studied 607 temporal bones in 318 patients: both bones in 289
42 individuals (90.9%), left bone in 11 individuals (3.4%) and right bone in 18
43 individuals (5.7%). Temporal bones were excluded from the study
44 whenever anatomical alterations of labyrinth had occurred and when the
45 assessment of tegmen tympani status, the degree of mastoid pneumatization
46 or the thickness of the superior semicircular canal roof could not be
47 evaluated by means of CAT scans. Women accounted for the 56.7% of the
48 sample. The mean age of the patients in the present work was 50.440 years
49 (SD 19.242 years); age ranged 2 to 88 years and 196 patients (61.6%) were
50 older than 45 years.

51 The studies were performed by means of multi-slice helical
52 computed tomography equipment (Philips Brilliance 6); the images were
53 obtained on the axial plane with the patient's neck in hyperextension,
54 avoiding direct radiation damage to crystalline lens. In all cases, both
55 coronal and Pöschl plane reconstructions were carried out. The "raw data"
56 have been reconstructed by using a bone algorithm. For image acquisition
57 and formatting, the radiological protocols were as follows: 2 × 0.6 mm
58 collimation, 0.65 mm slice thickness, 0.32 mm slice increase, 0.75

59 seconds rotation time, 0.38 piCTh, 120 CV, 300 mAs, 1024 × 1024 matrix,
60 180 mm field of vision, 0.5 mm reconstruction thickness and 0.5 mm
61 reconstruction increase.

62 The TT status was evaluated in the coronal and Pöschl plane
63 reconstructions. Absence of bone between the middle ear and the middle
64 cranial fossa in one or more CAT reconstructions characterized dehiscence
65 (TTD); otherwise, integrity (TTI) was assessed.

66

67 **STATISTICAL METHODOLOGY**

68 All statistical analyses were performed by using the IBM SPSS v.19
69 software (SPSS, Chicago, IL. USA). Pearson's χ^2 test was applied for TT
70 status and SSC pattern independence. Bonferroni's correction was applied
71 to multiple comparisons on total data.

72 We also calculated Spearman's rho (ρ), a nonparametric measure
73 of statistical dependence between two ordinal variables. In order of
74 increasing thickness, SSC patterns were codified as 0 (SSCD), 1
75 (papyraceous or thin), 2 (normal) and 3 (thick or pneumatized). Since
76 pneumatized patterns always showed a thickness > 1.8 mm, thick and
77 pneumatized patterns were grouped together in category 3. TTD and TTI
78 were codified as 0 and 1, respectively.

79 The analysis of variance (ANOVA) was used to compare mean SSC
80 thickness for the different TT statuses. This analysis allowed the
81 incorporation of several covariates (including age as a quantitative
82 variable) and of factors (such as sex) to adjust as possible confusion
83 variables. The significant differences were quantified by *a posteriori*
84 simple contrasts.

85 A multivariate binary logistics regression was used to estimate the
86 TTD probability as a function of SSC pattern, considering age and sex as
87 confusion variables. Nagelkerke's determination coefficient estimated the
88 proportion of the total outcome variation explained by the model.

89

90 **RESULTS**

91 The distribution of the five categories of SSC thickness in our patients
92 was as follows: 23 SSCD (3.79%); 68 papyraceous or thin (11.20%); 466
93 normal or classic (76.77%); 30 thick (4.94%) and 20 pneumatized (3.29%).
94 As said before, thick and pneumatized individuals were grouped together in
95 category 3 for further analyses (50 cases, 8.23%). Regarding TT, 66 TTD
96 cases and 541 TTI cases were observed (10.87% and 89.13% respectively).

97 TTD was more frequent in the SSCD category (34.78%) than in the
98 rest of the SSC levels (9.93%). Conversely, the percentage of TTI was
99 higher in non-dehiscent SSC (90.07%) than in SSCD (65.22%). Pearson's
100 χ^2 test provided a significant association between TT status and SSC
101 dichotomous classification ($\chi^2 = 11.102$; $p = 0.001$); the ρ value was 0.152
102 ($p < 0.01$).

103 Table 1 shows the observed distribution of SSC patterns and TT
104 statuses. We detected a highly significant association between SSC pattern
105 and TT status ($\chi^2 = 28.073$; $p < 0.001$). Multiple comparisons indicated that
106 the TT status was significantly differently associated with the SSCD and
107 papyraceous patterns compared to the normal, thick and pneumatized
108 patterns ($p < 0.05$). As shown in Table 1, TTD percentages were higher in
109 the SSCD and papyraceous patterns, and TTI percentages were higher in
110 the normal and thick patterns. A positive and highly significant ρ value was
111 found ($\rho = 0.200$, $p < 0.001$); higher values of the ordinal variable SSC
112 pattern were associated with higher values of the ordinal variable TT status.

113 The mean SSC thickness were 0.732 mm (SD 0.435 mm) and 1.062
114 mm (SD 0.523 mm) for TTD and TTI, respectively. The ANOVA detected
115 a highly significant difference between TTD and TTI for mean SSC
116 thickness after data adjustments for age and sex ($F=19.030$; $p<0.001$);
117 mean SSC thickness was higher for TTI, with an adjusted difference of
118 0.311 mm (95% interval of confidence: 0.171mm to 0.450mm).

119 Table 2 shows the parameters for the obtained logistic regression
120 model. The model was highly significant ($\chi^2 = 45.939$; $p<0.001$) and
121 explained 14.7 % of the total variation of TTD probability (Nagelkerke's
122 determination coefficient $R^2=0.147$).

123 Age showed a highly significant effect on TTD probability
124 ($p=0.003$), but sex showed no significant effect ($p=0.377$). No significant
125 age by sex interaction was detected ($p=0.593$). For each additional year of
126 age, the risk for TTD increased by 4.1% (95% interval of confidence: 1.4%
127 to 7.0%). SSC pattern had a highly significant effect on TTD probability:
128 as the SSC thickness decreased, the TTD probability increased. According
129 to the obtained results, thickness greater than 1.8 mm seems to be
130 associated with the lowest risk of TTD. Therefore, increased risk was
131 estimated on the basis of the kind of SSC pattern; a normal pattern did not
132 increase TTD probability, but the SSCD pattern was associated with a 20
133 times increased risk, and the papyraceous pattern was associated with a 12
134 times increase in risk.

135

136 **DISCUSSION**

137 As regards the percentage distribution of tomodensitometry patterns
138 of SSC bone coverage, our results were in accordance to Cisneros (16) but
139 differed from Kurt (4), who reported a lower proportion of normal pattern
140 (42%), a similar proportion of papyraceous pattern and a higher proportion
141 of thick (22%), pneumatized (12%) and SSCD (6.28%) patterns. These

142 differences might be explained by the different methods used for SSC
143 thickness evaluation; we always used CAT to calculate the minimum
144 thickness of SSC bone cover adjacent to the middle fossa, but Kurt (4)
145 considered the average of two measures by CBCT (cone beam computed
146 tomography) and provided no details about the selection of the positions for
147 measurement. The CBCT slices used were thinner than CAT slices. On the
148 other hand, patients' age could also explain these differences; in the present
149 work, the mean age was 50.440 years, while Kurt (4) studied younger
150 patients (mean age 37.4 years).

151 Nadaraja et al. (14) considered a 5-point scale for TT status:
152 integrity (grade 1), unifocal dehiscence <5 mm (grade 2), multifocal
153 dehiscence <5 mm (grade 3), unifocal or multifocal dehiscence > 5mm
154 (grade 4) and meningocele (grade 5). However, we considered dehiscence
155 TT status as a single category, regardless of its extension and cause, in
156 order to avoid sparsely represented categories and the consequent reduction
157 in the power of statistical tests.

158 Mahendran (10) suggested that both SSCD and TTD were caused by
159 a generalized deficiency of bone formation or deposition on the floor of the
160 cranial cavity; therefore, both defects should be considered as a unique
161 entity. Nadaraja (14) indicated that probability of TTD was 10.2 times
162 higher in patients with SSCD than in controls. However, we did not find
163 any previous report about possible associations between TT status and the
164 different SSC patterns.

165 We found that the SSCD and papyraceous patterns were significantly
166 associated with TTD while the normal and thick patterns were significantly
167 associated with TTI. Positive and significant ρ values were found, but since
168 they were below 1.00, the correlation between TT status and SSC pattern is
169 considered to be moderate. The quantitative analysis of SSC thickness

170 showed that mean thickness was higher for TTI, after adjusting for age and
171 sex, thus confirming the association between TT status and SSC pattern.

172 In a previous study about SSCD and TTD, Nadaraja et al. (14) did not
173 consider age and sex as significant risk factors. We have demonstrated the
174 significant effects of age and SSC pattern on TTD occurrence, but
175 significant effects were detected for neither sex nor for age by sex
176 interaction. Bone loss in both sexes over age 50 results from age related
177 osteoblast dysfunction (17) and increase of osteoclast activity (18). Our
178 results were in according to Crovetto et al. (19), who report that a scarce
179 bone resorption of the labyrinth (causing a slight thinning of SSC roof) is
180 associated with age in both sexes, with a more pronounced effects in
181 postmenopausal women. Yu et al. (20) suggested an association between
182 SSCD and osteoporosis in a population of elderly East Asian women.
183 Davey et al. (21) found that bone overlying the labyrinth gets thinner over
184 time, but no significant differences were detected between men and
185 women.

186 The detected association between SSCD and TTD led us to a
187 reflection on daily clinical practice: when TTD occurs, either asymptomatic
188 or not, a CAT scan with Pöschl plane reconstructions should be
189 systematically carried out for detecting possible SSCD, as the choice of an
190 accurate surgical approach depends on the existence and extension of
191 altered temporal bone parts.

192

193 **CONCLUSIONS**

194 We found that dehiscence and very thin bone coverage of the superior
195 semicircular canal were significantly associated with dehiscence of tegmen
196 tympani. Both normal and thick bone coverage of this canal were
197 significantly associated with integrity of tegmen tympani. The risk for

198 dehiscence of tegmen tympani increased by 4.1% for each additional year
199 of age, did not differ significantly for normal and thick bone covering the
200 superior semicircular canal, and increased 12 times and 20 times for
201 papyraceous bone coverage and dehiscence of superior semicircular canal,
202 respectively.

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297

1 **TABLE 2.** *Multivariate binary logistics regression model, showing the*
 2 *effects of age by sex, age, sex, and SSC pattern on the probability of TTD.*

3

Variable	Coefficient (β)	P- value	RR	95% CI
Age by Sex	-0.009	0.593	0.991	0.957 to 1.025
Age	0.041	0.003	1.041	1.014 to 1.070
Sex	0.977	0.377	2.657	0.304 to 23.188
SSC pattern				
SSCD vs >1.8mm	3.007	0.007	20.228	2.291 to 178.561
≤ 0.5 mm vs. >1.8 mm	2.492	0.019	12.08	1.518 to 96.126
0.6mm - 1.7mm vs >1.8 mm	1.547	0.132	4.697	0.627 to 35.203

4

5 SSCD: semicircular superior canal dehiscence. TTD: tegmen tympani
 6 dehiscence. RR: risk ratio. CI: interval of confidence.

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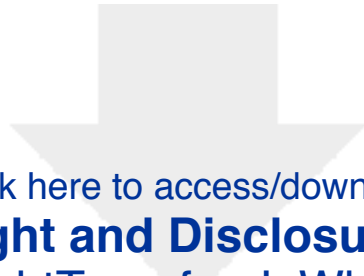
1 **TABLE 1.** *Distribution of tegmen tympani (TT) status and semicircular*
 2 *superior canal (SSC) pattern.*

3

TT status	SSC Pattern				Total
	SSCD	≤ 0.5 mm	0.6 - 1.7 mm	≥ 1.8 mm	
TTD	8 (34.8%) ^a	15 (22.1%) ^a	42 (9.0%) ^b	1 (2.0%) ^b	66 (10.8%)
TTI	15 (65.2%) ^a	53 (77.9%) ^a	424 (91.0%) ^b	49 (98.0%) ^b	541 (89.2%)

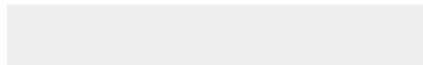
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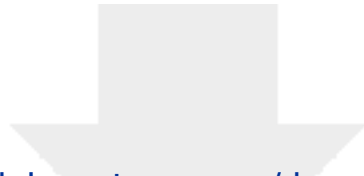
5 Data are reported as counts (%). SSCD: semicircular superior canal
 6 dehiscence. TTD: tegmen tympani dehiscence. TTI: tegmen tympani
 7 integrity. ^{a,b} Different letters mean significant differences ($p < 0.05$)



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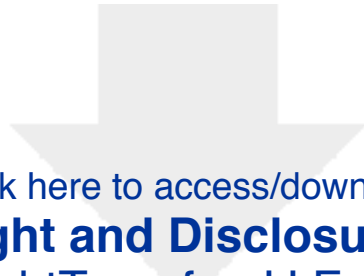




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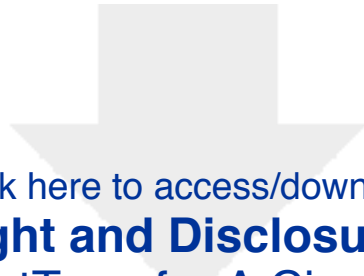
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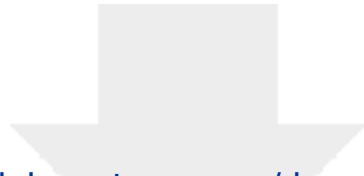
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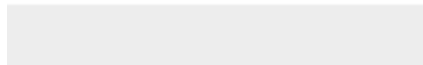
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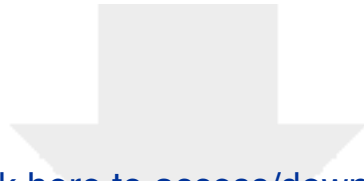




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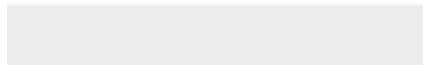
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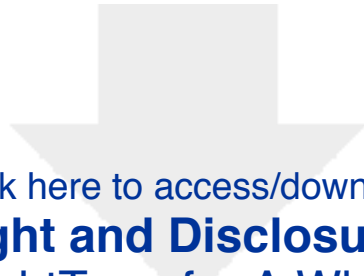




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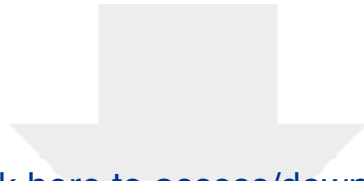
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