Lateral Skull Base Attenuation in Superior Semicircular Canal Dehiscence and Spontaneous Cerebrospinal Fluid Otorrhea

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Abstract
Objectives. (1) To quantitatively assess the lateral skull base thickness in patients with superior semicircular canal dehiscence (SSCD) using a standardized and validated radiographic measure and to compare it with that of a population with spontaneous cerebrospinal fluid otorrhea (CSFO). (2) To analyze demographic and clinical factors associated with skull base thickness in the SSCD group.

Study Design. Case series with chart review.

Setting. Tertiary neurotologic referral center.

Subjects and Methods. Based on computed tomography imaging of the tegmen, mean skull base thickness was calculated for 16 patients with radiographic and clinical SSCD. Similar measures were performed in 4 comparison groups consisting of adults with spontaneous CSFO (n = 33), as well as 3 control groups recruited from our adult cochlear implant database: 30 obese controls (body mass index [BMI] >30 kg/m²), 11 overweight controls (BMI, 25-30 kg/m²), and 20 normal weight controls (BMI <25 kg/m²).

Results. The SSCD group had a significantly lower mean BMI (28.6 kg/m²) than the spontaneous CSFO group (37.7 kg/m²; P = .0007). The mean skull base thickness of SSCD patients was 17% thinner than that of the CSFO group, 31% thinner vs obese controls, 49% thinner vs overweight controls, and 45% thinner vs normal weight controls. These differences were all statistically significant (P < .05).

Conclusion. Patients with SSCD have a marked thinning of the lateral skull base, more so than patients with spontaneous CSF otorrhea and control groups with different BMIs. Skull base attenuation in SSCD patients did not correlate with BMI.

Keywords
tegmen thickness, superior semicircular canal dehiscence, spontaneous CSF otorrhea

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Superior semicircular canal dehiscence (SSCD) was first described by Minor et al,¹ who reported the relation between dehiscence and pressure-induced vertigo and/or Tullio phenomenon. The pathoetiology of the dehiscence remains controversial.

The continued development of the superior canal until 3 years of age makes it possible for an early arrest of growth to predispose to the development of a dehiscence.²-⁶ Although the current literature favors a congenital predisposition toward SSCD, the symptoms do not occur until the thinning/dehiscence becomes clinically significant due to another mechanism.²,⁷-¹⁷ The observed association with other tegmen dehiscences, as well as the propensity toward bilateral SSCD or contralateral near dehiscence, raises the question of whether there is a specific local bone demineralization or a systemic mechanism that explains both pathologies occurring concomitantly.¹⁰,¹⁸-²⁵

In a previous study at our institution, we described a standardized method to measure the mean skull base thickness (MSBT) in patients with spontaneous cerebrospinal fluid otorrhea (CSFO), using 6 predefined measurement points along the tegmen tympani and the tegmen mastoideum.²⁶ This group demonstrated that MSBT in patients with spontaneous CSFO whose mean BMI was 36.6 kg/m² was significantly thinner than that of a control group composed of adult obese cochlear implant users. A significant

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inverse correlation was also detected between MSBT and elevated BMI. Given the above findings, we hypothesized in this study that patients with SSCD would have a thinner MSBT when compared with patients with spontaneous CSFO and other matched controls. Our aims were to quantify the MSBT of SSCD patients and other groups using the technique described by Stevens et al.²⁶ to explore possible demographic and clinical variables that may be associated with a thinner MSBT.

Material and Methods

Study Approval

Approval was obtained from the Institutional Review Board (Pro00023289) of the Medical University of South Carolina.

Group Selection

We conducted a retrospective review from 2004 to 2015 using ICD-9 codes (International Classification of Diseases, Ninth Revision) and operative notes as well as a full-text search within radiology reports to include all adult patients with SSCD. Other inclusion criteria were the availability of an interpretable computed tomography (CT) scan that included Pöschl and Stenvers planes to help aid in establishing the diagnosis of SSCD, as well as coronal sections to perform the measurements of tegmen thickness. The Pöschl transverse pyramidal plane is a parasagittal oblique plane that is 45° from the sagittal and coronal planes. It also sections the petrous bone in a plane perpendicular to its axis. In this plane, the superior semicircular canal appears as a ring, with the entire arc of the outer wall displayed on 1 image. The Stenvers plane is a parasagittal plane perpendicular to the Pöschl plane, and it images the superior cortex of the superior semicircular canal in cross section. Two patients in the SSCD group had near dehiscence, defined as extreme thinning of the bone overlying the superior semicircular canal with bone still present, and had associated clinical and electrophysiologic evidence of a third window syndrome. Two additional patients had a frank symptomatic dehiscence on one side and a near dehiscence on the contralateral side.

The spontaneous CSFO group consisted of adult patients (≥18 years) diagnosed with spontaneous CSFO, with available CT scans of the temporal bone with reformatted in the coronal plane. After reviewing the imaging of the CSFO group, we isolated a subset of patients who had an associated near dehiscence of the superior semicircular canal (CSFSSCD). We defined near dehiscence as very thin bone overlying the superior semicircular canal, with absence of bone over the canal on at least 1 cut in the coronal plane. Since these CT scans were not reformatted in the Pöschl or Stenvers plane, a dehiscence could not be definitively diagnosed.

For each patient, we obtained demographic data, clinical presentation, as well as BMI from the electronic medical record at either the last clinic visit or the time of surgery. Exclusion criteria included a history of temporal bone trauma, cholesteatoma/chronic ear disease, neoplasms, prior lateral skull base or mastoid surgery, and congenital inner ear anomaly.

We consecutively recruited 31 obese cochlear implantees (BMI > 30 kg/m²) and 31 nonobese cochlear implantees (BMI < 30 kg/m²) from our adult cochlear implant database. We separated the latter group into 2 subgroups: normal weight (BMI < 25 kg/m²) and overweight (BMI, 25-30 kg/m²). The inclusion criteria were otherwise identical to those of the spontaneous CSFO group with available temporal bone CT scans reformatted in the coronal plane.

Imaging and Hardware

The analyzed temporal bone CT scans were all obtained with a standard collimation of 0.625 mm. Images were reconstructed in axial, coronal, and sagittal planes, as well as in the parasagittal Pöschl and Stenvers planes for the SSCD group. The majority of the scans were obtained at our institution on either a Siemens Somatom Sensation 16 or a Siemens Definition 128 (Siemens Medical Solutions, Malvern, Pennsylvania). Spatial resolution was rated as accurate to 0.1 to 0.2 mm per this protocol.²⁷

Software-reformatted images were analyzed via the proprietary digital radiology imaging system AGFA Impax 6 (AGFA Impax, Mortsel, Belgium). Temporal bone thickness was measured via the partial volume averaging formula (measurement caliper) in this software. Accuracy was rated to 0.1 mm.

CT Measurement Algorithm

As previously reported,²⁶ skull base measurements were performed at 3 predefined points bilaterally along the tegmen tympani and tegmen mastoideum (Figure 1). For the tegmen tympani, measurements were performed on a coronal section that best depicts the malleus, the incus, and at least 2 turns of the cochlea. The tegmen plate thickness was measured at its thickest and thinnest points and at a point directly superior to the ossicles. For the tegmen mastoideum, measurements were performed on a coronal section that shows the most lateral curvature of the posterior semicircular canal. The tegmen plate was measured at its thickest and thinnest and at a point directly in the center of the plate midway between the otic capsule and the cortical squamous bone. Owing to limitation of the measurement calipers, the minimum measurable limit of skull base thickness was 0.4 mm. We applied this minimum limit even to grossly dehiscent areas where no obvious bone was seen.²⁶ The 6 tegmen measurements allowed us to calculate for each patient a mean aggregate thickness of the skull base on an individual side and bilaterally.

Validation of the Measures

Three operators at different levels of training (a medical student, a senior level otolaryngology resident, and a second-year neurotology fellow) made the measurements of the spontaneous CSFO and control groups. The measures of the MSBT for the spontaneous CSFO and control groups were
previously validated with a mean intraclass correlation coefficient (ICC) ranging from good (>0.61) to very good (>0.81).26 Two neurotology fellows and 1 experienced neurotologist made measurements for the SSCD group. One of the raters was not blinded to the study group. The 2 other raters were blinded to the study group as well as to each other’s measurements. We calculated the ICC among all 3 raters and between the 2 blinded raters and classified the strength of agreement as follows: <0.20, poor; 0.21-0.40, fair; 0.41-0.60, moderate; 0.61-0.80, good; 0.81-1.00, very good. We used the average of the 3 raters’ MSBT measures to perform the comparison with the other groups.

Statistics
All analyses were performed with Sigma Plot 12.5 (Systat Software Inc, San Jose, California) and MedCalc 13.3.0.0 (MedCalc Software bvba, Ostend, Belgium). Disease information and demographic variables were summarized. Continuous variables were described by mean ± standard error of the mean. Nominal variables were summarized by the frequency and percentage. All continuous variables were tested for normal distribution as determined by the Kolmogorov-Smirnov test. For continuous variables, comparisons were made by a 1-way analysis of variance when the distribution was normal and equality of variance was assumed. One-way analysis of variance on ranks was used when the distribution was not normal and there was an inequality of variances. Post hoc multiple comparison analysis, using Dunn’s test, was performed when the Kruskal-Wallis showed a difference between the groups. A value of P < .05 was considered indicative of statistical significance.

Results
A total of 28 patients (20 females and 8 males) were identified with a radiographic diagnosis of SSCD or a clinical suspicion of SSCD from 2004 to 2015. Of these, 21 patients had CT scans available for review. Five patients were subsequently excluded because the scans were not available for all 3 raters or they lacked appropriate reformatting to perform the measures. The tegmen thickness was measured in the remaining 16 CT scans and the medical records reviewed for sex, age, BMI, clinical presentation, and audiograms when applicable. These results are summarized in Table 1.

Forty-two patients with spontaneous CSFO were identified. Thirteen of these patients had significant thinning of the bone over the arcuate eminence and absence of bone on at least 1 cut on the coronal plane, which we defined as near dehiscence. These patients were analyzed as a separate group (CSFSSCD). Twenty-six patients in the spontaneous CSFO group and 7 patients in the CSFSSCD group had adequate CT scans to perform the lateral skull base thickness measurements. Our control population consisted of 31 obese patients and 31 consecutive nonobese controls selected to match the obese group. These control subjects had a preoperative CT scans as part of the evaluation for a cochlear implant. Eleven of these patients had a BMI between 25 and 30 kg/m², and 20 had a BMI <25 kg/m².

All groups did not differ significantly in regard to age (P = .25). The mean BMI of the SSCD group was 28.6 ± 1.7 kg/m² and was significantly lower than the BMIs of the spontaneous CSFO and obese control groups (P < .0001). The CSFSSCD group had a lower mean BMI than the rest of the CSFO patients, 34.0 ± 2.6 vs 37.7 ± 1.4 kg/m², but this difference did not reach significance. In addition, the difference in BMI between the CSFSSCD group and the SSCD group did not reach significance (Table 2).

Three raters measured tegmen thickness for the SSCD group. The mean ICC among the 3 measures was 0.60, suggesting moderate agreement. This ICC increased to 0.71 when the 2 blinded raters were compared (Table 3).

The MSBT in the SSCD group was 0.68 ± 0.02 mm. This was significantly thinner as compared with all the other groups, except for the CSFSSCD group. The MSBT in

Figure 1. Radiographic measurement technique. (A) Tegmen tympani. The 3 points defined on each side were the thinnest point (dehiscent tegmen, white arrowhead), the thickest (1.5 mm), and a standard point directly cephalad to the ossicle heads. The coronal cut shows at least 2 turns of the cochlea. (B) Tegmen mastoideum with the thinnest point measure at 0.4 mm, the thickest at 1.9 mm, and the standard midway point at 0.5 mm. The coronal cut shows the posterior most part of the posterior semicircular canal. (From Stevens SM et al. Novel radiographic measurement algorithm demonstrating a link between obesity and lateral skull base attenuation. Otolaryngol Head Neck Surg. 2015;152:172-179.)
the SSCD group of 0.68 mm was 17% thinner than that of the spontaneous CSFO group (0.82 ± 0.04 mm; \( P = .025 \)), 31% thinner vs obese controls (0.99 ± 0.03 mm; \( P < .0001 \)), 49% thinner vs controls with BMI between 25 and 30 (1.33 ± 0.07 mm; \( P < .0001 \)), and 45% thinner vs controls with normal BMI (1.23 ± 0.06 mm; \( P < .0001 \)). These results are summarized in Table 2.

A multiple linear regression model was then used to identify factors associated with a change in the MSBT in the SSCD group (dependent variable). Of all the demographic factors and the clinical symptoms with which our patients presented, only the amplitude of the highest air-bone gap was inversely correlated to the MSBT (\( \rho = -0.51; P < .05 \)). The model examined predictor variables reported in the literature (age, BMI, sex) in addition to the number of symptoms at presentation and conductive hearing loss. The following regression equation was obtained:

\[
MSBT = 0.0085 \times \text{age} + 0.0066 \times \text{BMI} - 0.12 \times \text{conductive hearing loss} + 0.022 \times \text{no. of symptoms} - 0.078 \times \text{sex}.
\]

The coefficient of determination \( R^2 \) equaled 0.98. Four of those variables were independently significant (\( P < .05 \), with age being the most significant (\( P = .00009 \)), whereas sex alone did not account for the MSBT variation (\( P = .17 \)). Age, BMI, conductive hearing loss, number of symptoms, and sex together accounted for 98% of the variation of the MSBT in this patient population (Table 4).

In Figures 2 and 3, coronal sections of the tegmen mastoideum and tegmen tympani from a patient of each group are displayed for comparison, respectively. On these images, the tegmen is homogeneously thinned in the SSCD group, as opposed to the “moth-eaten” appearance of the tegmen in the CSFSSCD and CSFO groups.

### Discussion

In the present study, we found that the SSCD group had a greater lateral skull base attenuation than did the other groups. Prior studies have reported a wide variation between SSDC and concurrent tegmen defects, ranging from 14% to 88%.\(^{18,25,28}\) Although our study did not attempt to quantify overall lateral skull base thickness, the MSBT has been validated as a reproducible measurement and serves as a useful correlate.\(^{26}\) When we quantitatively assessed tegmen mastoideum and tegmen tympani in our patient population, there was a significant difference with control groups and patients with spontaneous CSFO.

In addition, comparison among the groups showed that the SSCD patients had a significantly lower BMI than did the patients with CSFO. There was no difference in regard to age or sex ratio. Given the multiple linear regression model, we were able to infer that patients with SSCD and conductive hearing loss have a MSBT that is 0.12 mm thinner than that of patients without conductive hearing loss. How greater skull base attenuation may enhance bone conduction and/or diminish air conduction is yet to be determined.

Interestingly, age seemed to have a positive covariance with MSBT: for every increase in age of 1 year, the MSBT was 0.0085 mm thicker. The pediatric series of semicircular canal dehiscence reported in the literature agree that any developmental abnormality responsible for the SSDC is not necessarily congenital.\(^{14,17,29,30}\) SSDC was most common in children <1 year old. As age increased, the incidence of dehiscent or thin bone over the canal decreased.\(^{31}\) Although this explains the positive covariance, the relationship between age and lateral skull base attenuation is likely nonlinear and more complex. In fact, osteopenia related to age, especially in postmenopausal women, has been suggested to play a role in the bone demineralization process over the superior semicircular canal. A 10% decrease in thickness (0.1 mm) over 40 years of life has been reported in the bone overlying the superior semicircular canal.\(^{10,13,24}\) The multiple linear regression model did not show sex as an independent predictor factor. Large-sample studies analyzing the interaction term of sex × age are needed to further explore this relationship.

As with age, our model suggests a positive covariance between BMI and MSBT: with every 1-unit increase in BMI, there is an increase of 0.0066 mm in MSBT. We can draw comparison with the inverse relationship between BMI and risk fracture in osteoporosis.\(^{32}\) An increase in BMI is associated

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### Table 1. Superior Semicircular Canal Dehiscence Group Demographics and Clinical Data.

<table>
<thead>
<tr>
<th>Variable</th>
<th>n or Mean (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>16</td>
</tr>
<tr>
<td>Dehiscence</td>
<td></td>
</tr>
<tr>
<td>Unilateral</td>
<td>11</td>
</tr>
<tr>
<td>Bilateral</td>
<td>5</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>5</td>
</tr>
<tr>
<td>Female</td>
<td>11</td>
</tr>
<tr>
<td>Age, y</td>
<td>59 (38-76)</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>28.6 (21.6-45.9)</td>
</tr>
<tr>
<td>Clinical presentation(^{a})</td>
<td></td>
</tr>
<tr>
<td>Asymptomatic</td>
<td>0</td>
</tr>
<tr>
<td>Tullio phenomenon</td>
<td>7</td>
</tr>
<tr>
<td>Valsalva-induced dizziness</td>
<td>4</td>
</tr>
<tr>
<td>Hypercus</td>
<td>10</td>
</tr>
<tr>
<td>Autophony</td>
<td>9</td>
</tr>
<tr>
<td>Nonspecific dizziness/imbalance</td>
<td>12</td>
</tr>
<tr>
<td>Aural fullness</td>
<td>9</td>
</tr>
<tr>
<td>Tinnitus</td>
<td>11</td>
</tr>
<tr>
<td>Pulsatile tinnitus</td>
<td>6</td>
</tr>
<tr>
<td>Hearing loss</td>
<td>10(^{b})</td>
</tr>
</tbody>
</table>

\(^{a}\)Two of our patients who presented with hearing loss were referred to us following a failed stapedectomy in both cases. Except for these 2 patients, the 14 other had at least 2 complaints that could be related to their superior semicircular canal dehiscence.

\(^{b}\)Of 10 audiograms, 9 were available for review, and in all of them, we measured conductive hearing loss with an air-bone gap present at the low frequencies.
with an increase in bone mineral density (BMD). This increase in BMD does not necessarily confer greater strength, since obesity may alter the composition of bone via secreted adipokines and other cytokines or via an associated hypovitaminosis D or increased mineralocorticoid release, without affecting BMD. Using our standardized radiographic measurements, Stevens et al previously established that patients with spontaneous CSFO had a MSBT that is thinner than that in obese controls.26 Even though the mean BMI of our SSCD group was 28.6 kg/m², 8 patients (50%) had a BMI <25 kg/m², and only 3 were obese (including 1 with a BMI of 46 with obstructive sleep apnea). This is in stark contrast with the CSFO group, where the mean BMI was 37.7 and only 3 patients (11%) had a BMI <30 kg/m² but still >25 kg/m². We postulate that there are likely processes, independent of BMI, contributing to the lateral skull base attenuation in patients with thinning over the otic capsule bone or with SSCD.28,36-43

Table 2. Comparison of Age, BMI, and Overall MSBT among the Subgroups. a

<table>
<thead>
<tr>
<th></th>
<th>SSCD</th>
<th>CSFO</th>
<th>CSFSSCD</th>
<th>Obese</th>
<th>Overweight</th>
<th>Normal BMI</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients, n</td>
<td>16</td>
<td>26</td>
<td>7</td>
<td>30</td>
<td>11</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Mean age, y</td>
<td>59</td>
<td>56</td>
<td>68</td>
<td>55</td>
<td>58</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>BMI, a kg/m²</td>
<td>28.6 ± 1.7</td>
<td>37.7 ± 1.4 b</td>
<td>34 ± 2.6</td>
<td>34.6 ± 0.9 b</td>
<td>27.5 ± 0.4</td>
<td>21.6 ± 0.5</td>
<td>&lt;.0001 b</td>
</tr>
<tr>
<td>Sex ratio, F:M</td>
<td>2.2</td>
<td>5.5</td>
<td>1.3</td>
<td>1.3</td>
<td>0.4</td>
<td>1.2</td>
<td>89</td>
</tr>
<tr>
<td>MSBT, a mm</td>
<td>0.68 ± 0.02</td>
<td>0.82 ± 0.04 b</td>
<td>0.69 ± 0.06</td>
<td>0.99 ± 0.03 b</td>
<td>1.33 ± 0.07 b</td>
<td>1.23 ± 0.06 b</td>
<td>&lt;.05 b</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; CSFO, cerebrospinal fluid otorrhea; CSFSSCD, cerebrospinal fluid superior semicircular canal dehiscence; F, female; M, male; MSBT, mean skull base thickness; SSCD, superior semicircular canal dehiscence.

aValues presented as mean ± standard error of the mean.
bSignificant difference with the SSCD group (P < .05).

Table 3. Individual Raters’ Mean Skull Base Thickness for Each Patient in the SSCD Group.

<table>
<thead>
<tr>
<th></th>
<th>Rater 1</th>
<th>Rater 2</th>
<th>Rater 3</th>
<th>Mean Aggregate Thickness of 3 Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient 1</td>
<td>0.65</td>
<td>0.78</td>
<td>0.90</td>
<td>0.78</td>
</tr>
<tr>
<td>Patient 2</td>
<td>0.61</td>
<td>0.40</td>
<td>0.86</td>
<td>0.62</td>
</tr>
<tr>
<td>Patient 3</td>
<td>0.81</td>
<td>0.68</td>
<td>0.72</td>
<td>0.74</td>
</tr>
<tr>
<td>Patient 4</td>
<td>0.69</td>
<td>0.54</td>
<td>0.47</td>
<td>0.57</td>
</tr>
<tr>
<td>Patient 5</td>
<td>0.7</td>
<td>0.67</td>
<td>0.58</td>
<td>0.65</td>
</tr>
<tr>
<td>Patient 6</td>
<td>0.62</td>
<td>0.45</td>
<td>0.49</td>
<td>0.52</td>
</tr>
<tr>
<td>Patient 7</td>
<td>0.64</td>
<td>0.46</td>
<td>0.56</td>
<td>0.55</td>
</tr>
<tr>
<td>Patient 8</td>
<td>0.75</td>
<td>0.80</td>
<td>0.56</td>
<td>0.70</td>
</tr>
<tr>
<td>Patient 9</td>
<td>0.73</td>
<td>0.87</td>
<td>0.54</td>
<td>0.71</td>
</tr>
<tr>
<td>Patient 10</td>
<td>0.67</td>
<td>0.58</td>
<td>0.57</td>
<td>0.61</td>
</tr>
<tr>
<td>Patient 11</td>
<td>0.63</td>
<td>0.75</td>
<td>0.64</td>
<td>0.67</td>
</tr>
<tr>
<td>Patient 12</td>
<td>0.70</td>
<td>0.70</td>
<td>0.89</td>
<td>0.76</td>
</tr>
<tr>
<td>Patient 13</td>
<td>0.88</td>
<td>1.12</td>
<td>0.86</td>
<td>0.95</td>
</tr>
<tr>
<td>Patient 14</td>
<td>0.67</td>
<td>0.65</td>
<td>0.68</td>
<td>0.67</td>
</tr>
<tr>
<td>Patient 15</td>
<td>0.78</td>
<td>0.72</td>
<td>0.54</td>
<td>0.68</td>
</tr>
<tr>
<td>Patient 16</td>
<td>0.68</td>
<td>0.72</td>
<td>0.73</td>
<td>0.71</td>
</tr>
<tr>
<td>SSCD group a</td>
<td>0.70 ± 0.02</td>
<td>0.68 ± 0.04</td>
<td>0.66 ± 0.03</td>
<td>0.68 ± 0.02</td>
</tr>
</tbody>
</table>

**ICC**

<table>
<thead>
<tr>
<th></th>
<th>All 3 raters</th>
<th>0.60</th>
<th>Moderate agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blinded raters</td>
<td>0.71</td>
<td></td>
<td>Strong agreement</td>
</tr>
</tbody>
</table>

Abbreviations: ICC, intraclass correlation coefficient; SSCD, superior semicircular canal dehiscence.

aValues in mean ± standard error of the mean.
measurements done for the SSCD group were made by 1 unblinded rater and 2 blinded raters. Despite obtaining moderate to good intraclass correlation on the mean measured aggregate thickness, a review of the individual measured points shows variability mostly in the tegmen mastoideum measures. This is in part due to the subjectivity of the rater in selecting the thickest point, as well as limitations in manipulating the measuring caliper. The variability of the tegmen mastoideum measurement has also been noted for the CSFO group.26

In addition, although this measurement technique has been validated and has showed good reliability, there still is potential for measurement bias. The minimal spatial resolution in our software protocol is 0.4 mm. This is also correlated to the rate of false-positive CT scans in superior canal dehiscence and the discrepancy between a radiologically positive CT scan and the existence of a true dehiscence during surgical exploration. Cone beam volumetric tomography may palliate these technical limitations in the future.44,45

**Conclusion**

Our study is the first to quantitatively measure the MSBT in patients with SSCD using a previously validated technique. The homogeneously thin skull base in these patients...
suggests that pathophysiologic processes, independent from obesity, play a role in the development of the dehiscence in a specific subset of patients who may be congenitally predisposed or have an early developmental predisposition. Studies with larger sample sizes, especially examining the subgroup of patients with both a spontaneous CSFO and radiographic and/or clinical SSCD, may give some answers. The relation between (1) the specific complaints and/or the number of complaints of patients with SSCD and (2) the level of skull base attenuation may provide some explanation regarding the discordance between radiographic evidence of dehiscence and lack of symptoms.

Author Contributions

Habib G. Rizk, design, data collection, data analysis, draft, review; Jonathan L. Hatch, data collection, data analysis, draft, review; Shawn M. Stevens, design, data collection, data analysis, review; Paul R. Lambert, data analysis, manuscript review; Ted A. Meyer, data analysis, manuscript review.

Disclosures

Competing interests: None.
Sponsorships: None.
Funding source: None.

References


Figure 3. Comparison of tegmen tympani taken from the study groups. The scans were chosen from patients who had the closest mean skull base thickness to the mean of the whole group. BMI, body mass index; CSFO, cerebrospinal fluid otorrhea; CSFSSCD, cerebrospinal fluid SSCD; SSCD, superior semicircular canal dehiscence.


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