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ORIGINAL ARTICLE

MDCT of Dehiscent or Thin Bone Coverage over the Superior Semicircular Canal: Assessment of Prevalence by Age and Contralateral Canal Bone Thickness

MDBT'de Defektif ya da İnce Süperior Semisirküler Kanal Kemik Örtüsü: Yaş ve Kontralateral Kanal Kemik Kalınlığına Göre Prevalansın Değerlendirilmesi

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ABSTRACT

Objective: Superior semicircular canal dehiscence (SSCD) describes the presence of a defect in the superior bone coverage of the membranous SSC. The etiology of the defect is not known and its reported CT prevalence is variable. This study primarily aimed to report MDCT prevalence of SSCD and thin bone coverage over SSC among different age groups. A secondary aim was to assess for any association between SSCD and the thickness of contralateral bone coverage over SSC.
Materials and Methods: Temporal bone MDCTs were retrospectively evaluated for SSCD and the thickness bone coverage over SSC. The prevalence of SSCD and thin bone coverage over SSC among five different age groups and the thickness of bone over SCC in SSCD and non-SSCD subjects were analyzed.
Results: Five hundred and nine subjects (1018 ears) were included in the study. Age-adjusted models did not demonstrate a significant association between the age groups and the prevalence of SSCD (p=0.63) or between the age groups and the prevalence of thin bone coverage over SSC (p=0,81). Unilateral SSC roof thickness of ≤ 0.5 mm was significantly associated with increased prevalence of contralateral SSCD (p=0.05 and p=0.04). In subjects without radiological evidence of SSCD, right-or left-sided thin bone coverage over SSC was significantly associated with contralateral thin bone coverage (p<0.00).
Conclusions: This study did not find an increasing trend in the prevalence of SSCD and thin bone coverage of SSC roof with increasing age. In subjects with unilateral SSCD, the thickness of the contralateral SSC roof was significantly lower than in non-SSCD subjects.

Keywords: Multidetector computed tomography, superior semicircular canal dehiscence, temporal bone

ÖZ

Amaç: Süperior semirsiküler kanal dehisansı (SSKD), membranöz SSK'yi örten kemikte bir defekt bulunmasını tanımlar. Bu defektin etiyolojisi bilinmemekte olup literatürde bilgisayarlı tomografi (BT) incelemelerinde bildirilen SSKD prevalansları değişkenlik göstermektedir. Bu çalışmada başlıca, multidedektörlü BT'de (MDBT) farklı yaş gruplarındaki hastalarda SSKD ve ince SSK kemik örtüsü prevalanslarının saptanması amaçlanmıştır. Diğer bir amaç ise SSKD ve SSK kemik örtüsünün ince olması ile kontralateral SSK kemik örtüsü kalınlığı arasında bir ilişki bulunup bulunmadığının değerlendirilmesidir.
Gereç ve Yöntem: Temporal kemiğin MDBT incelemeleri SSKD ve SSK kemik örtü kalınlığı açısından retrospektif olarak değerlendirildi. Beş farklı yaş grubundaki hastalar arasında SSKD ve ince SSK kemik örtü prevalansları ile SSKD'si bulunan ve bulunmayan hastalarda SSK kemik örtü kalınlıkları değerlendirildi.
Bulgular: Çalışmaya 509 hastanın temporal MDBT incelemeleri (1018 kulak) dahil edildi. Yaşa göre modellemeler, farklı yaş gruplarındaki hastalar arasında SSKD ya da ince SSK kemik örtü prevalanslarının anlamlı bir değişim göstermediğini ortaya koydu (p=0.63 ve p=0,81). Bir kulakta SSK kemik çatı kalınlığının 0.5 mm ya da altında olması ile karşı kulakta artmış SSKD prevalansı arasında istatistiksel olarak anlamlı bir ilişki bulundu (p=0.05 ve p=0.04). SSKD'si bulunmayan hastalarda sağ ya da sol kulak SSK kemik çatısındaki incelik ile karşı kulak SSK kemik çatısındaki incelik arasında anlamlı ilişki mevcuttu (p<0.00).
Sonuç: Bu çalışmada artan yaş ile birlikte SSKD ya da ince SSK kemik örtüsü prevalanslarının da artış gösterdiğine dair bir bulgu saptanmadı. Bir kulakta SSKD'si bulunan hastalarda karşı kulaktaki SSK kemik çatı kalınlığı anlamlı olarak düşük bulundu.

Anahtar kelimeler: Multidedektör bilgisayarlı tomografi; süperior semirsirküler kanal dehisansı; temporal kemik

Introduction

Superior semicircular canal dehiscence (SSCD) syndrome occurs due to a defect in the superior bone coverage of the membranous superior semicircular canal (1). In addition to oval and round windows, the defective bone in SSSD acts as a third window for the membranous labyrinth. Sound and pressure changes occurring in the middle ear and the middle cranial fossa are abnormally conducted to the membranous labyrinth. Clinically, the syndrome is characterized by sound- or pressure-induced vestibular symptoms

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such as vertigo, nystagmus, oscillopsia, and auditory symptoms such as autophony and hyperacusis. The diagnosis requires a combination of symptoms, positive vestibular-audiological tests, and positive cross-sectional imaging findings. Computed tomography (CT) is the most commonly used imaging method to confirm the diagnosis by displaying the defect of the bone coverage of the SSC (2,3).

Subjects with CT evidence of dehiscence can be asymptomatic. In such cases, a protective role of the dura mater at the location of the bone defect has been suggested (3). Also, CT may overcall SSCD due to its limitations in demonstrating a thin but intact bone coverage of the SSC (4). Initial CT studies on the radiologic prevalence of SSCD found dehiscence rates as high as 9% to 12% (5,6), while anatomic studies reported rates between 0.5% to 0.7% (4,7). Obtaining high-resolution CT images with a slice thickness of 0.625 mm or less, and reformatting images in the planes of the SSC (Stenvers and Pöschl planes) have been reported to increase diagnostic specificity by preventing false-positive results (8).

Although the syndrome has been first described in 1998 by Minor et al., its etiology is still under debate. A large cadaveric study demonstrating no evidence of bone remodeling at the location of dehiscence proposed a congenital basis for SSCD (7). In CT studies, observation of high frequency of bilateral SSCD, high prevalence of SSCD in developing ears of infants up to 3 years of age, and high prevalence of contralateral thin bone coverage in cases of unilateral SSCD suggested a primarily congenital etiology (3). Contrarily, some CT studies found an increase in the prevalence of SSCD and thin bone coverage of SSC as the age advances, suggesting an age-related acquired component to the syndrome (9-11). SSCD has also been associated with bone thinning in neighboring temporal structures, giving rise to tegmen defects, geniculate ganglion dehiscence, and thinning of the bone over the internal acoustic canal (12-14).

This study primarily aimed to assess the prevalence of SSCD and thin bone coverage over SSC among different age groups in a large sample of high-resolution temporal bone CTs. A secondary aim was to assess for any association between SSCD and the thickness of the contralateral bone coverage over SSC, by analyzing the radiologic thickness of bone over SCC in SSCD and non-SSCD subjects.

Materials and Methods

Subjects

The study was approved by the institutional review board. Using Picture Archiving and Communicating System (PACS) database, consecutive temporal bone CT scans performed between October 2011 and December 2012 were retrospectively reviewed. An initial review included all CT scans, regardless of the clinical indication. Patients were excluded from the study if their images exhibited any evidence of congenital inner ear malformations, temporal bone trauma, destructive processes affecting the inner ear structures, or labyrinthitis ossificans. Patients under 3 years old were also excluded from the study since the otic capsule continues its development during these first years of life.

Imaging protocol and data collection:

All images were acquired using a 64-channel CT scanner (Aquillion 64, Toshiba, Tokyo, Japan) with a slice thickness of 0.5 mm, 120 kV peak, 300 mAs, 0.5 sec. rotation time, 2,24 cm/sec pitch. Following the initial review of the scans, patients' age and sex were recorded. Raw data of the scans included in the study were transferred to a workstation, where the semicircular canals were reviewed with multiplanar reconstructions, using a DICOM viewer application (Vitrea; Vital Images). The scans were evaluated by two radiologists (with 14 years and 4 years of experience in neuroradiology and general radiology, respectively) who were blinded to patients' age and sex information at the time of the reviews. Every superior semicircular canal was evaluated in two perpendicular planes (Poschl-oblique sagittal and Stenvers-oblique coronal planes). "Dehiscence" was defined as a focal discontinuity of the bone overlying the canal, that is observed on both perpendicular planes (Figures 1a and 1b). Dehiscent/non-dehiscent decision was made in consensus. The ears with no evidence of superior semicircular canal dehiscence were then randomized for evaluation of the thickness of the bone overlying the superior semicircular canal. On the Poschl plane, the thickness of the thinnest location of the bony roof of the superior semicircular canal was measured vertically by one reader (Figures 2a and 2b). The average of two consecutive measurements was used. Each ear of each patient was evaluated independently, in random order. The recorded measurements were grouped into 2 categories as ≤ 0.5 mm or ≥ 0.6 mm.

Statistical analysis

Statistical calculations were performed using the SPSS software package (IBM, Armonk, NY). Continuous variables were reported as means with standard deviations, and categorical variables were presented as percentages. Hypothesis tests were 2-sided, and a P-value of.05 was the threshold for the tests of significance. Patient age was categorized into 5 groups as 4-19 years, 20-39 years, 40-59 years, 60-79 years, and 80-99 years. For categorical variables, comparisons were performed using Pearson's chi-squared test. For evaluation of the trend in prevalence ratios of superior semicircular canal dehiscence and the canal bone thickness by different age categories, logistic linear regression models were used.

Results

Temporal bone CT scans of 509 subjects (1018 temporal bones) were included in the study. Two hundred and thirty-three (233) subjects were male (45.8%) and 276 subjects were female (54.2%). The age range of the subjects was 4-82 years, with a mean age of 40.93 years (SD = 17.17).

Radiological dehiscence of SSC was identified in 31 subjects (6%) and 38 ears (3.7%). Of the 31 subjects with CT evidence of canal dehiscence, 15 were males (48.3%) and 16 were females (51.6%). Subject- or ear-based analysis of the prevalence of SSCD did not reveal a statistically significant difference between gender groups (p = 0.58).

For each age group, calculated prevalence of SSCD and thin bone coverage over SSC are presented in Table 1 and Table 2. Age-adjusted models did not demonstrate a statistically significant association between the age groups and the prevalence of SSCD (p = 0.63), or between the age groups and the prevalence of thin bone coverage over SSC (p = 0,81).

In 17 out of 24 subjects with unilateral SSCD (70.8%), contralateral canal roof thickness was 0.5 mm or below. Unilateral SSC roof thickness of 0.5 mm or below was statistically significantly associated with increased prevalence of contralateral SSCD (p = 0.05 and p = 0.04, for the left and right semicircular canal roof thicknesses of 0.5 mm or below, respectively) (Table 3 and Table 4)

In subjects without radiological evidence of SSCD, right- or left-sided thin bone coverage over SSC (a roof bone thickness of 0.5 mm or below) was statistically significantly associated with contralateral thin bone coverage over SSC (p < 0.00). Correlatively, a right- or left-sided roof thickness of 0.6 mm or above was statistically significantly associated with a contralateral roof thickness of 0.6 mm or above (p < 0.00) Table 5.

Table 1. Subjects with SSCD, distribution among age groups.

Age group (years)	Total (n)	Subjects with thin bone coverage of SSC (n)	Subjects with thin bone coverage of SSC (%)
4-19	71	2	2.8
20-39	162	11 (1*)	9.1
40-59	208	15 (5*)	7.2
60-79	63	3 (1*)	4.7
80-99	5	0	0

*****, Number of the subjects with bilateral SSCD dehiscence.

Table 2. Subjects with thin bone coverage over SSC, distribution among age groups.

Age group (years)	Total (n)	Subjects with thin bone coverage of SSC (n)	Subjects with thin bone coverage of SSC (%)
4-19	71	40 (24*)	56.3
20-39	162	84 (40*)	51.8
40-59	208	117 (70*)	56.2
60-79	63	26 (13*)	41.2
80-99	5	3 (3*)	60.0

*****, Number of the subjects with bilateral thin bone coverage over SSC.

Table 3. Prevalence of contralateral SSCD by bone coverage thickness of the left ear.

Non- dehiscent (n / %)		Right SSC Dehiscent (n / %)		Total (n / %)	p
Bone coverage thickness *	**≤ 0.5 mm**	219 (95.6)	10 (4.4)	229 (100)	= 0.05
	≥ 0.6 mm	259 (98.5)	4 (1.5)	263 (100)	
Total		478 (97.1)	14 (2.9)	492 (100)	

*, Vertical thickness of the thinnest part of the bone canal on Poschl plane.

Table 4. Prevalence of contralateral SSCD by bone coverage thickness of the right ear.

Non- dehiscent (n / %)		Left SSC Dehiscent (n / %)		Total (n / %)	p
Bone coverage thickness *	**≤ 0.5 mm**	183 (96.3)	7 (3.7)	190 (100)	= 0.04
	≥ 0.6 mm	295 (99.0)	3 (1.0)	298 (100)	
Total		478 (97.9)	10 (2.1)	488 (100)	

*, Vertical thickness of the thinnest part of the bone canal on Poschl plane.

Table 5. Comparison of left SSC bone coverage thickness to that of right SSC

≤ 0.5 mm (n, %)		Right SSC bone coverage thickness* ≥ 0.6 mm (n, %)		Total (n, %)	p
Left SSC bone coverage thickness*	**≤ 0.5 mm**	150 (68.5)	69 (31.5)	219 (100)	< 0.00
	≥ 0.6 mm	33 (12.7)	226 (87.3)	259 (100)	
Total		183(38.2)	295(61.8)	478(100)	

*, Vertical thickness of the thinnest part of the bone canal on Poschl plane.

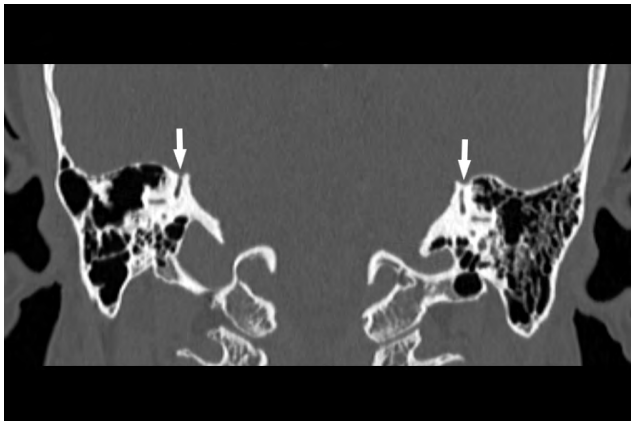

Figure 1a. Coronal CT image of a temporal bone at the level of the SSCs shows the defect of the bone coverage of the right SSC, at the level of the groove for the superior petrosal sinus (arrow). The bone coverage of the left SSC at the same level is intact (arrow).

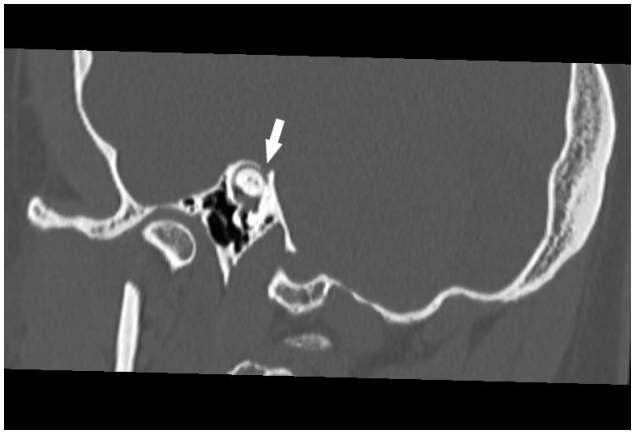

Figure 1b. Reformatted CT image of the right SSC on the plane of Poschl shows the discontinuity of the bone over the right membranous SSC, at the level of the groove for the superior petrosal sinus (arrow).

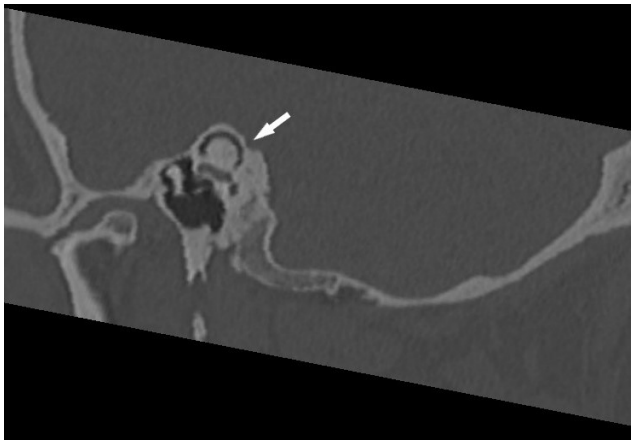

Figure 2a. A reformatted CT image of a non-dehiscent left SSC on the plane of Poschl shows the continuity of the bone over the left membranous SSC (arrow).

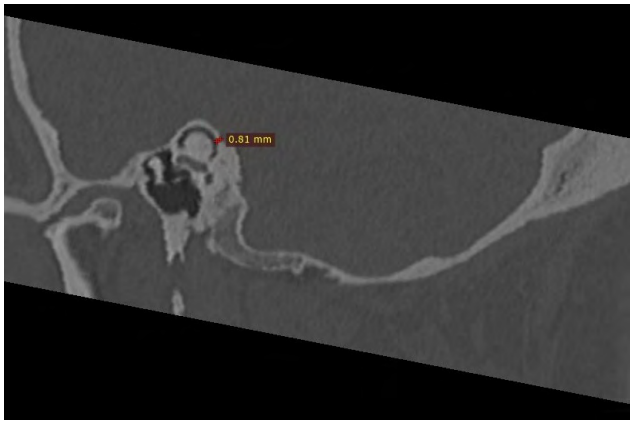

Figure 2b. Measurement of the thickness of the bone coverage of the non-dehiscent left SSC on the plane of Poschl. The thickness of the thinnest location of the bone coverage of the superior semicircular canal was measured vertically.

Discussion

Using a 64-channel CT scanner and a slice thickness of 0.5 mm, we found radiological evidence of SSCD in 3.7% of the 1018 ears and 6.0% of the 509 subjects. This prevalence is lower than the reported prevalence rates (of 8-12%) of the studies that used 1 mm slice thickness or 1 mm reconstruction intervals in the evaluation of the images, reflecting the effect of the image acquisition and reconstruction parameters on the dehiscence detection rates (5,6,15). The prevalence rate obtained in the present study is consistent with CT studies that used thin-section images (a slice thickness of 0.5 to 0.65 mm, and a slice interval of < 0.5 mm) and Poschl plane image reviewing, which found the prevalence rates between 3.6-4.9% in similar sample sizes (4, 8, 9, 13, 16). Still, these CT prevalence rates of SSCD are much higher than the rates reported in pathological-anatomic studies, which range between 0.5% to 0.6% (4,7). Two recent CT studies reported closer prevalence rates to that of the pathologic studies. Of these, Klopp-Dutote et al. (17), in the evaluation of Poschl plane images with 0.4-0.6 mm slice thickness and 0.1-0.2 mm interval, found the frequency of SSCD as 1.7%. That study, however, was limited by its small sample size of 180 individuals. Another study by Berning et al. (18) found CT evidence of superior semicircular canal dehiscence in 2% of a population of 500 asymptomatic individuals, using a 0.63 mm slice thickness and a spacing of 0.375 mm. Importantly, in a group of 110 symptomatic patients in the same study, CT prevalence of semicircular canal dehiscence was 13.6%. Therefore, in addition to imaging parameters used in CT studies, significantly different prevalence rates in the symptomatic and asymptomatic group of individuals may also partly explain the variations in reported prevalence rates among CT studies that retrospectively include both symptomatic and asymptomatic individuals.

The present study didn't find any significant association between the prevalence of canal dehiscence and the age categories. The prevalence of thin canal covering (≤ 0.5 mm) also did not significantly differ among the age groups. This is in contradiction with the results of the study by Nadgir et al. (9), who, in a retrospective review of temporal bone CTs of 304 individuals between ages of 7 months to 89 years, found a statistically significant increase in the prevalence of superior semicircular canal dehiscence as the age increases. Using a similar age-categorization and canal thickness classification, Sood et al. (11) compared the age categories of the individuals with canal dehiscence or canal thinning to that of with non-dehiscence and normal canal thickness in 80 subjects. They found a significant association between the prevalence of canal dehiscence, as well as the canal thinning and the increased age. However, the study was limited by the use of 1 mm collimation in image acquisition. Similar to our results, Kaur et al.'s study involving high-resolution temporal bone CTs (with slice thicknesses of 0.6 mm) of 76 asymptomatic individuals did not find a significant association between the dome thickness

of SSC and the age. Also, no significant association was found between the thinnest measurement of the SSC roof and the age (19). In Mahulu et al.'s study, the thinnest measurement of the SSC roof in cone-beam CTs of 311 individuals, SSC bone thickness also did not significantly differ between young (<45 years) and older (≥ 45 years) individuals (20). Excluding subjects ≤ 3 years old, we found SSCD prevalence lowest in the 4 to 20-year-old age category. This was in agreement with the study of Meiklejohn et al. (21), that in the young age group above 3 years, SSCD prevalence falls below the adult rates.

In a histological review of 1000 temporal bones, a thin bone coverage or dehiscence of SSC on one side was associated with a thin bone coverage on the contralateral side (7). In CT studies, Hirvonen et al. and Tello et al. found a significant association between the presence of unilateral SSCD and the contralateral SSC roof thinning (22,23). Contrarily, Nadgir et al. found no significant association between SSCD and contralateral canal thinning. The authors argued against a developmental basis and suggested that canal thinning occurs with aging, independently of dehiscence (9). Our data showed that unilateral SSC roof thickness of 0.5 mm or below was statistically significantly associated with increased prevalence of contralateral SSCD. Also, in subjects without radiological evidence of SSCD, we found that a right- or left-sided thin SSC coverage (roof bone thickness of 0.5 mm or below) was statistically significantly associated with contralateral thin SSC coverage ($p< 0.00$). The finding of a thin contralateral bone coverage of SSC in cases with unilateral SSCD probably suggests that the dehiscence mostly occurs in subjects who are affected by a process that causes both SSC roofs to be thin. This is reflected in the high bilaterality rate of SSCD in the present study (22%), as well as in reported CT studies (9,5% to 46%) (4-6,9,16,18). As we did not find an increasing trend in thinning of SSC roof with increasing age, the process does not seem to be directly linked to aging. Also, in the 4 to 20 years age group, we found the prevalence of thin bone coverage over SSC as high as 56%. Although this rate was not statistically significantly higher than the prevalence rate of thin SSC coverage in other age categories in the present study when considered with the low prevalence rate of SSCD in the same age group (4-20 years), it may imply a developmental predisposition, that, in later stages of life, may put some subjects at risk for SSC dehiscence.

The present study is limited by its retrospective observational design. Although we did not aim to assess the symptomatology, lack of assessment of patient data on SSCD symptoms and including both symptomatic and asymptomatic may have affected the results. Also, the radiological dehiscence in the study was not confirmed clinically or surgically. Having one reviewer for consecutive measurements of SSC bone thickness is another drawback of the study.

In this MDCT study of 1018 temporal bones, the prevalence of SSCD (3.7%) was higher than that in anatomic-pathologic studies. Neither the prevalence of SSCD nor the prevalence of thin SSC bone coverage was statistically significantly associated with increased age. The distribution of thin bone coverage over SSC was even among different age groups. The prevalence rate of SSCD was below the adult rates in the 4 to 20-year-old age category. These findings, along with statistically significant association between unilateral SSCD and contralateral thin bone coverage, high bilaterality rates of SSCD, and thin bone coverage over SSC in the study support a developmental predisposition for SSCD.

The authors declare no conflict of interest.

Author Contributions: Conception: Ç.Ö., Data Collection and Processing: Ç.Ö., Design: Ç.Ö., Supervision: S.Ş., A.İ., Analysis and Interpretation: Ç.Ö., S.Ş., Literature Review: Ç.Ö., Writer: Ç.Ö., Critical Review: S.Ş., A.İ.

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