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Temporal CT of the Pneumatized Petrous Apex: Associated Anomalies and the Relationship with Tinnitus and Vertigo

Havalı Petröz Apeksin Temporal BT ile Değerlendirilmesi: Eşlik Eden Anomaliler ve Tinnitus ve Vertigo ile Arasındaki İlişki

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Abstract/Öz

Introduction: The aim of the present study was to determine concomitant congenital anomalies and variations of the temporal bone in patients with a pneumatized petrous apex and to investigate the relationship of non-pulsatile subjective tinnitus and peripheral vertigo with petrous apex pneumatization.

Methods: Temporal multidetector computed tomography (MDCT) images of 2120 patients were obtained from the hospital's digital database between 2009 and 2017. The MDCT scans were performed for various preliminary diagnoses including non-pulsatile subjective tinnitus, peripheral vertigo, hearing loss, otitis, and otalgia. Petrous apex pneumatization was detected in 192 patients. Twenty-six patients with temporal bone trauma were excluded from the study. One hundred sixty-six patients were included in the study. Temporal bone MDCT images were evaluated for concomitant congenital anomalies and variations.

Results: The incidence of diffuse petrous apex pneumatization was 9%. Excessive temporal bone pneumatization and high jugular bulb (JB) were found to be most prevalent in patients with petrous apex pneumatization. There were statistically significant differences between petrous apex pneumatization and peripheral vertigo (p=0.009). However, there were no statistically significant differences between petrous apex pneumatization and non-pulsatile subjective tinnitus (p=0.62).

Conclusion: The most common variation was the high JB, and the most common anomaly was the dehiscent internal carotid artery in patients with petrous apex pneumatization. Moreover, there was no statistically significant relationship between non-pulsatile subjective tinnitus and unilateral or bilateral petrous apex pneumatization.

Keywords: Petrous apex pneumatization, tinnitus, vertigo, temporal, multidetector computed tomography

Amaç: Bu çalışmanın amacı petröz apeks havalanması olan hastalarda temporal kemikte eşlik eden konjenital anomalileri ve varyasyonları saptamak, non pulsatil subjektif tinnitus ve peripheral vertigonun petröz apeks havalanması ile ilişkisini araştırmaktır.

Yöntemler: 2.120 hastanın temporal çok kesitli bilgisayarlı tomografi (ÇKBT) görüntüleri 2009-2017 tarihleri arasında kulak çınlaması, baş dönmesi, işitme kaybı, otit ve kulak ağrısı gibi çeşitli ön tanıları bulunan hastalarda hastanenin dijital veri tabanından taranmıştır. 192 hastada petröz apeks havalanması saptandı. Travma saptanan 26 hasta çalışma dışı bırakıldı. Çalışmaya dahil edilen166 hastanın temporal ÇKBT görüntüleri eşlik eden konjenital anomaliler ve varyasyonlar açısından değerlendirildi.

Bulgular: Diffüz petröz apeks havalanma insidansı %9 olarak saptandı. Petröz apeks havalanması olan hastalarda aşırı temporal kemik havalanması ve yüksek juguler bulbus en sık görülen bulgulardı. Petroz apeks havalanması ile peripheral vertigo arasında istatiksel olarak anlamlı ilişki bulundu (p=0,009). Ancak, petroz apeks havalanması ile non pulsatil subjektif tinnitus arasında istatistiksel olarak anlamlı ilişki saptanmadı (p=0,62).

Sonuç: Petröz apeks havalanaması olan hastalarda en sık görülen varyasyon yüksek jugüler bulbus ve en yaygın anomali dehisent internal carotid arterdir. Ayrıca, non pulsatil subjektif tinnitus ile tek taraflı veya bilateral petroz apeks havalanması arasında istatistiksel olarak anlamlı bir ilişki saptanmadı.

Anahtar Kelimeler: Petrous apex havalanması, tinnitus, vertigo, temporal, çok kesitli bilgisayarlı tomografi

Introduction

In adults, pneumatization of the temporal bone is divided into five regions: middle ear, squamomastoid (mastoid), perilabyrinthine, petrous apex, and accessory air cells (1). The petrous apex of the temporal bone is pyramidal in shape at the base of the skull between the greater wing of the sphenoid bone anteriorly and the occipital bone posteriorly (2). It consists of dense bone tissue and bone marrow. Petrous apex lesions can be classified as developmental, inflammatory, benign, malignant, vascular, and osseous dysplasias (2). Petrous apex pneumatization and asymmetric fatty marrow are the normal variants. If the air cells surrounded by epithelial cells communicate with the mastoid air cells, the petrous apex can be pneumatized (2). A previous study reports a wide range of incidence of petrous apex pneumatization ranging from 9% to 30% (1). Pneumatization can be highly variable, involving a large portion of the petrous temporal bone or only a small posterolateral segment. Many pathological conditions, such as inflammation, infection, and accumulation of fluid, can be observed in the pneumatized air cells in the petrous apex. In addition, extensive temporal bone pneumatization associated with tinnitus has been reported in previous studies (3, 4). The aim of the present study was to determine concomitant congenital anomalies and variations of the temporal bone in patients with petrous apex pneumatization and to investigate the relationship of non-pulsatile subjective tinnitus and peripheral vertigo with petrous apex pneumatization.

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Methods

Ethics committee approval was received for this study from the ethics committee of Ondokuz Mayıs University School of Medicine (April 3, 2017; no: B.30.2.ODM.0.20.08/792) The records of all patients who underwent temporal bone multidetector computed tomography (MDCT) between 2009 and 2017 were reviewed. MDCT images of 2120 patients were obtained from the hospital's digital database, and scans were performed for various preliminary diagnoses. The Digital Imaging and Communications in Medicine files were retrieved from the archive system and transferred to the OsiriX workstation for review, and all temporal MDCT images were evaluated for petrous apex pneumatization and associated anomalies and variations. Of the 2120 patients, 192 were detected with either bilateral or unilateral petrous apex pneumatization following a preliminary diagnosis of tinnitus, vertigo, hearing loss, otitis, otalgia, and trauma (Table 1). Preliminary diagnoses of the patients were obtained from the digital database of the hospital. Accordingly, 26 patients with trauma were excluded from the statistical analysis except to determine the incidence rate of petrous apex pneumatization. MDCT examinations were evaluated by two board-certified radiologists who had 15 years and 5 years of experience in head and neck imaging. The final decisions regarding the findings were determined by consensus.

High-resolution MDCT imaging was performed using a 16-slice multidetector row computed tomography scanner (Aquilion 16 system; Toshiba Medical Systems Corporation, Tokyo, Japan). The scanning parameters used were a collimation of 1 mm, 250 mAS, 120 kV, 512×512 matrix, bony algorithm, and 0.5 mm reconstruction thickness.

Table 1. Preliminary diagnosis of patients before performing MDCT

Medical information of the patients	Female	Male	Total
Non-pulsatile subjective tinnitus	11	11	22
Vertigo	14	5	19
Hearing loss	37	41	78
Otitis	18	17	35
Otalgia	8	4	12
Trauma	11	15	26
Total	99	93	192

MDCT: multidetector computed tomography

Temporal bone pneumatization was classified according to the method described by Han et al. (5). The sigmoid sinus was used as a reference for evaluation. On the image in which the malleoincudal complex resembled an ice cream cone, three parallel lines at 45° anterolaterally were applied so that one line crossed the most anterior point of the sigmoid sinus at its junction with the petrous bone, the second line crossed the most lateral margin along the transverse plane of the sigmoid groove, and the third line crossed the most posterior point of the sigmoid sinus, respectively. Grade I, with reduced pneumatization (hypopneumatization), is represented by mastoid cells positioned anteromedially to the most anterior line. Grade II, with moderate pneumatization, is represented by pneumatized cells extending between the first and the second lines. Grade III, with good pneumatization, is represented by pneumatized cells between the middle and the last lines. Grade IV, with hyperpneumatization, is represented by pneumatic cells situated posterolaterally to the last line (5). In the present study, Grade IV is accepted as extensive temporal bone pneumatization.

Written informed consent was obtained from the patients who participated in the present study.

Statistical Analysis

The Statistical Package for the Social Sciences version 20 for Windows (IBM SPSS Corp.; Armonk, NY, USA) was used for all statistical calculations. The Pearson's chi-squared test was used for the evaluation of the association between qualitative variables. Binary logistic regression analysis was used for the evaluation of binary values for dependent variables, affecting the prognostic factor.

Mean, standard deviation, and proportion were used as descriptive statistics. A p value of <0.05 was considered as statistically significant. All data are expressed as mean±SD.

Results

Of the 2120 temporal MDCT scans that were reviewed, 192 (9%) scans were found to have a pneumatized petrous apex. The mean age of the patients was 37.5±20 years. Of the 192 patients, 99 (51.6%) were females (mean age: 37.8±20.6 years), and 93 (48.4%) were males (mean age: 37.1±19.4 years). Table 1 shows the preliminary diagnoses of patients with petrous apex pneumatization. According to temporal MDCT images (Figure 1), petrous apex pneumatization was bilateral in 87 (45.3%) patients, with 55 (28.6%) on the right side (Figure 2) and 50 (26%) on the left side. By gender, the percentages of bilateral petrous apex pneumatization were 43.4% for females and 47.3% for males (Table 2), and there was no significant difference between petrous apex pneumatization and gender (p=0.83).

Table 2. Petrous apex pneumatization according to gender

			Pneumatization of the petrous apex			
			Bilateral	Right	Left	Total
Gender	Male	Count	44	25	24	93
		%	47.3	26.9	25.8	100.0
	Female	Count	43	30	26	99
		%	43.4	30.3	26.3	100.0
Total	Count	87	55	50	192	
	%	45.3	28.6	26.0	100.0	

Twenty-six patients with temporal bone trauma were excluded from the study. The medical records showed that preliminary diagnoses of the remaining 166 patients were non-pulsatile subjective tinnitus (13.2%), vertigo (11.4%), hearing loss (46.3%), otitis (35%), and otalgia (7.2%). Table 3 shows the temporal MDCT findings of patients with petrous apex pneumatization. Excessive temporal bone pneumatization (57.2%) and high jugular bulb (JB) (21.7%) were found to be the most prevalent variations in patients with petrous apex pneumatization.

The preliminary diagnosis in 22 of the 166 patients was non-pulsatile subjective tinnitus. Of the 22 patients, 12 were females (mean age: 44.5±22.8 years), and 10 were males (mean age: 50.7±13 years). Table 4 shows the temporal MDCT findings of these patients with non-pulsatile subjective tinnitus. Of the 166 temporal MDCT images, 45 were normal, excluding petrous apex pneumatization. Of the preliminary diagnoses, 11 of the 45 patients had non-pulsatile subjective tinnitus (24.4%). Unilateral

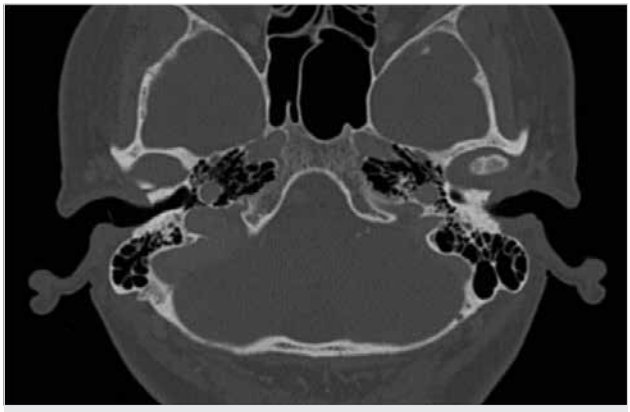

Figure 1. Axial high-resolution temporal bone computed tomography shows bilateral symmetry and almost equal diffuse pneumatization of the petrous apex

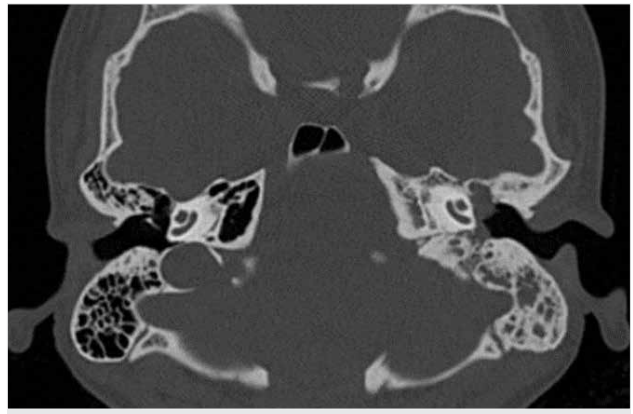

Figure 2. Axial high-resolution temporal bone computed tomography reveals right-sided petrous apex pneumatization and high jugular bulb

Table 3. Temporal MDCT findings of the patients

MDCT findings of the patients	Bilateral	Right	Left	Total
Excessive pneumatization in the temporal bone	47	23	25	95
High JB	6	18	12	36
Dehiscent JB	2	5	3	10
Dehiscent ICA	12	7	9	28
Otosclerosis	3	2	0	5
Otitis	4	9	13	26
Cerebellopontine angle tumor	0	3	0	3
Dehiscent semicircular canal	1	1	3	5
Congenital anomalies	6	2	2	10

MDCT: multidetector computed tomography; JB: jugular bulb; ICA: internal carotid artery

Table 4. Temporal MDCT findings of patients with tinnitus

MDCT findings of patients with tinnitus	Bilateral	Right	Left	Total
Excessive pneumatization in the temporal bone	8	3	4	17
High JB	1	4	0	5
Dehiscent JB	0	0	0	0
Dehiscent ICA	3	1	3	7
Otosclerosis	0	0	0	0
Otitis	0	0	1	1
Cerebellopontine angle tumor	0	1	0	1
Dehiscent semicircular canal	0	0	0	0
Congenital anomalies	0	1	0	1

MDCT: multidetector computed tomography; JB: jugular bulb; ICA: internal carotid artery

Table 5. Logistic regression analysis of tinnitus

MDCT findings of patients with tinnitus	B	S.E.	Wald	df	p	Exp (B)
High JB	-0.002	0.27	0.00	1	0.99	0.10
Dehiscent JB	-17.15	6633.19	0.00	1	0.99	0.00
Dehiscent ICA	0.36	0.25	2.13	1	0.14	1.44
Otosclerosis	-18.75	13,623.12	0.00	1	0.10	0.00
Otitis	-0.48	0.40	1.40	1	0.23	0.62
Dehiscent semicircular canal	-7.95	7033.24	0.00	1	0.10	0.00
Age	0.03	0.01	5.80	1	0.01	1.03
Side of pneumatization	-0.164	0.50	0.10	1	0.74	0.85
Constant	-2.91	0.61	22.72	1	0.00	0.05

MDCT: multidetector computed tomography; JB: jugular bulb; ICA: internal carotid artery

petrous apex pneumatization was found in 7 patients, and bilateral pneumatization was found in 4 patients. In addition, the temporal MDCT scans showed that 5 of the 11 patients had excessive pneumatization of the squamous part of the temporal bone. In 5 of the 7 patients with unilateral non-pulsatile subjective tinnitus, petrous apex pneumatization was detected on the same side. However, there was no statistically significant relationship between bilateral or unilateral petrous apex pneumatization and non-pulsatile subjective tinnitus (p=0.40). In addition, logistic regression analysis indicated that the risk of tinnitus increased 1.03-fold with age in patients with petrous apex pneumatization (Table 5).

The preliminary diagnosis in 19 of the 166 patients was vertigo, 14 of whom were females (mean age: 51±12.7 years), and 5 were males (mean age: 44.6±21.3 years). Vertigo was diagnosed by otolaryngologists, and patients with central vertigo were not included the study. Unilateral petrous apex pneumatization was detected in 5 of the 19 patients, and bilateral pneumatization was detected in 14 patients. Table 6 shows the temporal CT findings of patients with vertigo.

Eight of the 45 normal patients' preliminary diagnoses were peripheral vertigo (17.7%). Unilateral petrous apex pneumatization was found in 5 of the 8 patients, and bilateral pneumatization was found in 3 patients. Of the 8 patients, 4 had excessive pneumatization of the temporal bone. Logistic regression analysis indicated that the risk of peripheral vertigo was 3.4 times higher in patients with bilateral petrous apex pneumatization than in those with unilateral petrous apex pneumatization, and that the risk of peripheral vertigo increased 1.03-fold with age in patients with petrous apex pneumatization (Table 7).

Table 6. Temporal MDCT findings of patients with vertigo

MDCT findings of patients with vertigo	Bilateral	Right	Left	Total
Excessive pneumatization in the temporal bone	9	1	1	11
High JB	3	2	1	6
Dehiscent JB	0	1	0	1
Dehiscent ICA	5	0	0	5
Otosclerosis	0	1	0	1
Otitis	0	2	0	2
Cerebellopontine angle tumor	0	1	0	1
Dehiscent semicircular canal	0	0	1	1
Congenital anomalies	1	0	0	1

MDCT: multidetector computed tomography; JB: jugular bulb; ICA: internal carotid artery

Discussion

Petrous apex pneumatization occurs as a result of extensions from the supralabyrinthine, infralabyrinthine, and peritubal areas via the peritubal, posteromedial, and posterosuperior-subarcuate tracts (1). The degree of petrous apex pneumatization is closely related to squamomastoid (mastoid) pneumatization. According to extant literature, the incidence of petrous apex pneumatization ranges from 9% to 30% (6). In addition, the incidence of unilateral pneumatization has been reported as 4%-7% (1). In the present study, the incidence of petrous apex pneumatization was 9%, and the incidence of unilateral petrous apex pneumatization was 5%.

Variations of the temporal bone include high and dehiscent JBs, severe asymmetry of the jugular foramen, anteriorly located sigmoid sinus, deep sinus tympani, large internal auditory canal, and large cochlear aqueduct (7). An aberrant internal carotid artery (ICA) in the middle ear is a rare congenital finding with unknown etiology. These cases are encountered more often in females than in males and usually affect the right side (75%) (8). If ICA lacks the bony covering between the middle ear and the ICA, it is considered dehiscent. The reported incidence of carotid canal dehiscence is 1.4% (9). These patients generally suffer with otologic symptoms, such as tinnitus, vertigo, conductive hearing loss, and otalgia (8). We found that the incidence of the aberrant ICA and dehiscent carotid canal in patients with petrous apex pneumatization is 0.6% and 2.32%, respectively.

High JB is the most common vascular abnormality of the petrous part of the temporal bone, with an incidence of 3.5%-34% (9-11). It is defined as an extension of the JB superior to the level of the tympanic annulus (12). If the bony separation between the JB and the tympanic cavity is absent, it is called dehiscent JB (12). Unknown dehiscent JB can cause severe bleeding during surgical interventions, such as myringotomy and tympanomeatal flap elevation (13). JB anomalies can induce tinnitus, vertigo, and con-

Table 7. Logistic regression analysis of vertigo

MDCT findings of patients with vertigo	B	S.E.	Wald	df	p	Exp (B)
High JB	0.01	0.28	0.004	1	0.94	1.02
Dehiscent JB	-0.15	0.54	0.081	1	0.77	0.85
Dehiscent ICA	-0.34	0.37	0.824	1	0.36	0.71
Otosclerosis	-0.25	1.04	0.058	1	0.81	0.78
Otitis	-0.27	0.37	0.547	1	0.45	0.76
Dehiscent semicircular canal	0.26	0.50	0.260	1	0.61	1.29
Age	0.03	0.01	6.217	1	0.01	1.03
Side of pneumatization	1.33	0.57	5.453	1	0.02	3.81
Constant	-4.00	0.75	27.79	1	0.00	0.01

MDCT: multidetector computed tomography; JB: jugular bulb; ICA: internal carotid artery

ductive hearing loss due to erosion of the vestibular aqueduct and posterior semicircular canal (13). We found that the incidence of high JB and dehiscent JB in patients with petrous apex pneumatization is 21.6% and 6%, respectively.

Tinnitus is the most common otologic symptom worldwide with a prevalence of 30% (3). It often occurs in patients aged 40-70 years, with equal incidence in men and women (6). Causes of tinnitus include vascular anomalies, such as aberrant ICA, dehiscent ICA, stenosed ICA, high JB, and dehiscent JB, vascular pathologies, such as carotid canal dissection and fibromuscular dysplasia, and vascular neoplasms, such as paraganglioma, ossifying hemangioma, and osseous dysplasia, such as Paget's disease and otosclerosis (12).

Tinnitus has also been reported in patients with extensive temporal bone pneumatization and petrous apex pneumatization (3, 4, 6). However, a limited number of studies address the relationship between petrous apex pneumatization and tinnitus. It is believed that tinnitus may be due to large air cells between the ICA and the cochlea, acting as amplifiers and increasing the transmission of blood flow to the cochlea. Sözen et al. (6) evaluated the relationship between tinnitus and petrous bone pneumatization by comparing 25 patients with tinnitus with healthy individuals. Tinnitus was unilateral in 18 of the 25 patients and bilateral tinnitus in 7 patients. In addition, in 11 of the 18 patients with unilateral tinnitus, pneumatization was detected on the same side. There was no increase in temporal bone pneumatization in 7 of the 18 patients. In 5 of the 7 patients with bilateral tinnitus, pneumatization was detected as bilateral. In 1 of the 7 patients with bilateral tinnitus, pneumatization was detected on one side only. There was no increase in temporal bone pneumatization in one patient. Sözen et al. (6) detected petrous bone pneumatization in 22 (68.8%) of the 32 patients with tinnitus, which was statistically higher than the prevalence in control subjects (24%). In the present study, 22 temporal bone MDCT images of patients with tinnitus were evaluated. Dehiscent ICA, high JB, acoustic tumor, and aberrant ICA were detected in 11 of the 22 patients. The remaining 11 of the 22 patients' temporal bone MDCT images were completely normal. Petrous apex pneumatization was unilateral in 7 of the 11 patients and bilateral in 4 patients. In 5 of the 7 patients with unilateral petrous apex pneumatization, non-pulsatile subjective tinnitus was detected on the same side. However, there was no statistically significant relationship between non-pulsatile subjective tinnitus and bilateral or unilateral petrous apex pneumatization in patients with normal temporal bone MDCT scans (p=0.62). Therefore, we consider that petrous apex pneumatization cannot be the cause of non-pulsatile subjective tinnitus. Other concomitant anomalies or variations can lead to tinnitus in patients in coincidence with petrous apex pneumatization.

Vertigo is a subtype of dizziness that affects approximately 20%-30% of the population. It occurs in all age groups but is rare in children. The two types of vertigo are peripheral and central. Central vertigo is due to a disease or injury to the brain, such as head injuries, illnesses or infections, multiple sclerosis, migraines, brain tumors, strokes, and transient ischemic attacks. Peripheral vertigo is due to benign paroxysmal positional vertigo, vestibular neuronitis, Meniere's disease, labyrinthitis, perilymph fistula, and superior semicircular canal dehiscence syndrome. In addition, the relationship between vertigo and high JB, dehiscent JB, dehiscent semicircular canal, and cerebellopontine angle tumors has been reported in previous studies (8, 14). In the present study, eight temporal bone MDCT images of patients with peripheral vertigo were normal, and the other 4 of the 8 patients had excessive petrous bone pneumatization. We found a statistically significant association between peripheral vertigo and excessive petrous bone pneumatization (p=0.009). Therefore, increased pneumatization of the skull base may be due to peripheral vertigo, balance problems, and headaches. However, the incidence of peripheral vertigo in our study group is not any higher than that in the normal population. In addition, a limited number of studies have reported a relationship between vertigo and petrous apex pneumatization (15, 16).

Conclusion

In the present study, the incidence of petrous apex pneumatization was 9%. The most common variation was high JB, and the most common anomaly was dehiscent ICA in patients with petrous apex pneumatization. We found no statistically significant relationship between non-pulsatile subjective tinnitus and unilateral or bilateral petrous apex pneumatization.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Ondokuz Mayis University Faculty of Medicine (Approval Date: April 3, 2017; Approval No.: B.30.2.ODM.0.20.08/792).

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