The Journal of Global Radiology
ENSURING MEDICAL IMAGING ACCESS FOR ALL

SCHOLAR TWINNING

Temporal Bone Hyperpneumatization and Tinnitus: Clinico-Radiological Evaluation Using CT Scan

Sattar Razzaq Al-Esawi[1, 2], Ali Burair Hasan[2], Deepak Takhtani[3], Sarwat Hussain[3*]

[1] Neuroimaging Unit, Middle Euphrates Neuroscience Center, Najaf, Iraq
[2] Department of Radiology, Al-Sader Medical City, Najaf, Iraq
[3] Department of Radiology, University of Massachusetts Medical School

* **Corresponding author**. Current address: 55 Lake Avenue North, Worcester, MA 01655; sarwathussain@hotmail.com

OPEN ACCESS

DOI: 10.7191/jgr.2017.1034

Published: 9/5/2017

Citation: Al-Esawi SR, Hasan AB, Takhtani D, Hussain S. Temporal bone hyperpneumatization and tinnitus: Clinico-radiological evaluation using CT scan. J Glob Radiol. 2017;3(1):Article 5.

Keywords: Temporal bone hyperpneumatization, tinnitus, chronic sinusitis, otomastoiditis, concha bullosa, radiology

Word count: 2,240

Abstract

Purpose: We propose that there is increased incidence of subjective tinnitus (ST) in patients with temporal bone hyperpneumatization (TBHP). The secondary goal of this project is to assess the degrees of association of TBHP with paranasal sinus hyperpneumatization (PNSHP), chronic sinusitis (CS), otomastoiditis (OM) and concha bullosa (CB).

Methods and Materials: A total of 196 patients, who had computed tomography (CT) of the head for various clinical indications, were included in this study. CT head scans of patients with TBHP (n=96) were correlated with control patients (n=100). These patients had no apparent TBHP, history of ST, PNSHP, CS, OM or CB. The TBHP was graded based upon the extent of pneumatization. Size of the maxillary and sphenoid sinuses were also measured, providing pneumatization grade.

Results: Subjective tinnitus (ST) was present in 31 cases of TBHP and in 8 patients in the control group, which was statistically significant. Mean volume of maxillary sinus and the largest axial sphenoid sinus diameter were significantly larger in the cases of TBHP than in that of controls. Otomastoiditis was found in only 4 cases of TBHP (4%) and none of the controls; however, the difference was not statistically significant. Chronic sinusitis was present in 8 cases of TBHP and 5 of controls, and was also not statistically significant. Concha bullosa was significantly more frequent among cases of TBHP than controls.

Conclusion: There is a significant ($p < 0.001$) association between subjective tinnitus and increasing grade of temporal bone hyperpneumatization. There is a positive correlation between paranasal sinus hyperpneumatization and occurrence of concha bullosa, mimicking symptoms of sinusitis, with TBHP.

Introduction

TINNITUS is the perception of sound in the absence of an acoustic stimulus. It is a common symptom affecting about 30% of the population worldwide (1). Temporal bone hyperpneumatization (TBHP) has been implicated as a possible etiological factor in the development of subjective tinnitus (ST) (2).

The extent of pneumatization of the temporal bone can vary greatly between individuals according to age, history of temporal bone infection or surgical intervention (3). Temporal bone has five aerated compartments: middle ear, mastoid, perilabyrinthine, petrous apex and accessory regions which include squamous, zygomatic, styloid and occipital air cells (4). Five grades of temporal pneumatization have been described by Hans et al. (8) based on the size of the pneumatized bone. Embryologically, temporal bone air cells originate as an out-pouching from the lateral nasopharynx. These course up the eustachian tube (ET), through the middle ear and the aditus ad antrum into the mastoid antrum. Middle ear and perilabyrinthine air

ISSN 2372-8418

cell development are fairly consistent. Pneumatization of the mastoid and petrous bones can vary greatly (5).

TBHP may be associated with other aerated structures in the face. Concha bullosa, representing air-filled turbinates within the nasal cavity, is a normal variant occurring in 4-15% of normal subjects (6). When large, concha bullosa may obstruct the infundibulum and ostium of the ostiomeatal complex in the middle meatus, leading to sinusitis.

Methods and materials

Ninety-six patients with apparent TBHP and 100 control patients with normal pneumatization were included in this case-control study, performed at Middle Euphrates Neuroscience Center, Al-Sader Medical City from December 2015 to December 2016. Exclusion criteria for TBHP cases and controls were as follows: any CT findings which could explain tinnitus, such as cerebello-pontine angle (CPA) tumor, aberrant course of carotid artery (ICA), dehiscent jugular bulb, high jugular bulb, glomus jugulare tympanicum, trauma, or previous surgery. The mean age was 36.5 ± 4.7 years in the study cases and 36.4 ± 5.1 in the control group. The male to female ratio was 1.1 to 1.

All patients were referred for CT scan of the head for various clinical indications. Patients' reported presence or absence of subjective tinnitus were recorded. CT studies were done on 64-row multi-detector CT (Philips, Brilliance). The exposure settings were 80-120 kVp, and 100-300 mA, optimized for each patient according to the type of examination. The axial images of temporal bone, along with coronal and sagittal reformatted images, were reviewed by consultant radiologists with 5-7 years post-radiology boards experience.

Pneumatization was graded using criteria described previously (8).

Grade 0: Pneumatization confined to the mastoid region as shown in Figure 1a. This was the normal pattern of pneumatization present in controls.

Grade I: Pneumatization still confined to the mastoid region, but apparently of a larger volume (bulbous), with posterior extension of air cells beyond the posterior lip of the sigmoid sinus plate, as shown in Figure 1b.

Grade II: Pneumatization extending to the peri-tubal region of petrous apex, which is seen along the anterolateral aspect of ET and carotid canal, as shown in Figure 1c.

Grade III: Pneumatization extending along the anteromedial aspect of carotid canal in the petrous apex, as shown in Figure 1d.

Grade IV: Pneumatization extending to the squamous part of temporal bone, as shown in Figure 1e.

Grade V: Pneumatization extending to accessory regions, such as the occipital bone, cervical vertebrae, styloid process or zygomatic portion of temporal bone, as rarely reported in the literature (7). This pattern of pneumatization was not encountered in our study.

Figure 1a. Grade 0 pneumatization

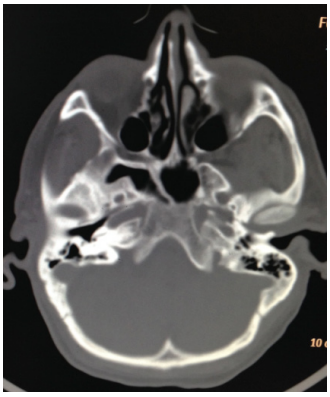


Figure 1b. Grade I pneumatization

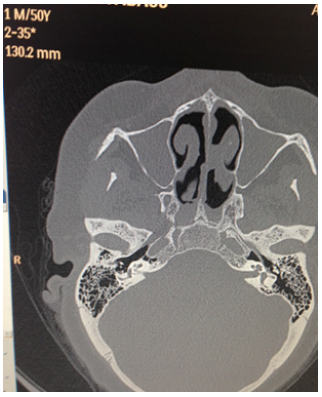


Figure 1c. Grade II pneumatization

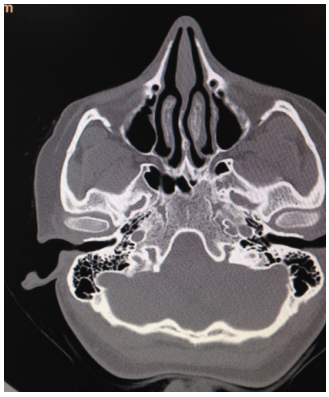
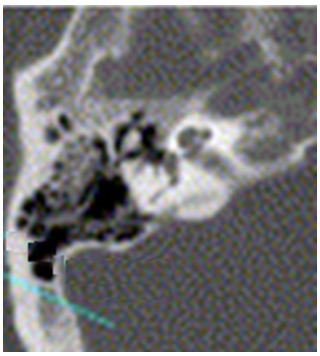


Figure 1d. Grade III pneumatization

Figure 1e. Grade IV pneumatization

Figure 2. Method of assessment of posterior temporal bone pneumatization.



Figures 3a-3b. Demonstration of measurement of maxillary sinus diameters in patient with grade I pneumatization.

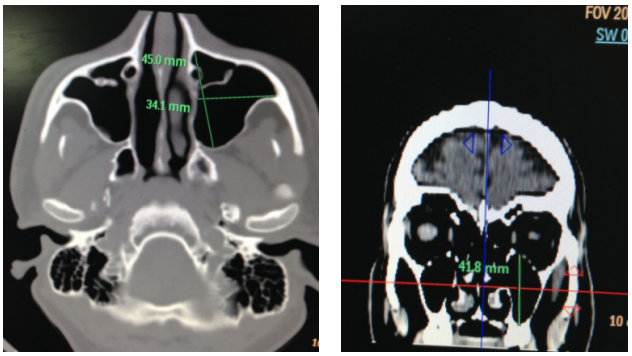


Figure 4. Demonstration of measurement of largest transverse diameter of sphenoid sinus in patient with Grade IV pneumatization.

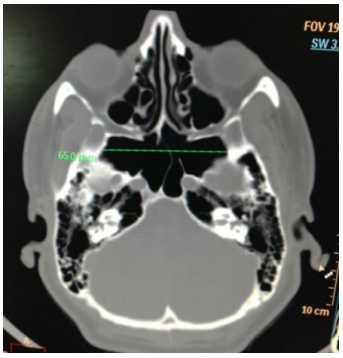


Figure 5. Coronal reconstruction CT of PNS showing bilateral concha bullosa.

The statistical package for social sciences (SPSS) software version 21, 2013, was used for analysis and management of data. Descriptive statistics were presented as numbers and percentages in addition to the mean and standard deviation. A chi-squared test was used to compare frequencies and to assess the significance of differences; Fisher's exact test was used as an alternative, when chi-square was inapplicable. Student's t test (independent 2 sample type) was used to compare mean volume of maxillary sinus and mean sphenoid diameter between the study groups. Analysis of variances (ANOVA test) was used to assess the significance of differences in mean volume of maxillary sinus and mean sphenoid diameter according to grades. Level of significance (P value) of ≤ 0.05 was considered a significant difference or relationship; finally, the results and findings were presented in tables and or figures with appropriate explanation for each.

The degree of posterior pneumatization of temporal bone is estimated by evaluation of the air cells around the sigmoid sinus on axial CT images at the level of the malleo-incudal complex. An arbitrary line is drawn transversely across the most posterior aspect of sigmoid sinus and any extension of air cells beyond this line is regarded as hyperpneumatization (HP) of the mastoid (8), as shown in Figure 2.

The posterior pneumatization of temporal bone was categorized into two degrees according to the distance from this arbitrary line; an extension of 10 mm distance or less was considered first degree, and any extension beyond that was regarded as second degree.

Maxillary and sphenoid sinuses only were selected for the measurement of the volume and the largest axial diameter, respectively, as these can be measured consistently. The following maximum dimensions for each maxillary sinus were measured:

(a) Maximum cranio-caudal diameter (length)

(b) Maximum antero-posterior diameter (depth)

(c) Maximum transverse diameter (width)

The volume of each maxillary sinus was calculated using the following equation: (length × depth × width × 0.5) (9), as shown in Figure 3.

Length was obtained from coronal reformatted CT images.

Depth and width were obtained from true axial CT sections.

The largest axial diameters of both sphenoid sinuses were measured, as shown in Figure 4.

Standard criteria were used for the presence of otomastoiditis, chronic sinusitis and concha bullosa (Figure 5).

All patients with apparent temporal bone hyperpneumatization (n=96) were asked about the presence or absence of subjective tinnitus.

Table 1. Distribution of tinnitus among cases and controls.

Tinnitus	Study Cases		Controls		Total	
	No.	%	No.	%	No.	%
Yes	31	32.3	8	8.0	39	19.9
No	65	67.7	92	92.0	157	80.1
Total #	96	49.0	100	51.0	196	100.0
OR (95%) CI = 5.48 (3.17 – 11.30) P. value < 0.001 sig *						
* OR = odds ratio, CI = confidence interval, sig = significant						

Table 2. Relationship between TBHP grading and demographic characteristics of patients.

Variable No.		Grade 1 (n=10)		Grade 2 (n=25)		Grade 3 (n=45)		Grade 4 (n=20)		*P*
		%	No.	%	No.	%	No.	%		
Age	≤ 20	1	10.0	2	8.0	4	8.9	3	15.0	0.81
	21 – 40	6	60.0	15	60.0	21	46.7	8	40.0	
	> 40	3	30.0	8	32.0	20	44.4	9	45.0	
Gender	Male	6	60.0	15	60.0	21	46.7	10	50.0	0.70
	Female	4	40.0	10	40.0	24	53.3	10	50.0	
Laterality	Unilateral	1	10.0	0	0.0	2	4.4	2	10.0	0.24
	Bilateral	9	90.0	25	100.0	43	95.6	18	90.0	

Table 3. Relationship between grading of TBHP with Volume of maxillary sinus and sphenoid diameter.

Variable	Grade 1 (n=10)	Grade 2 (n=25)	Grade 3 (n=45)	Grade 4 (n=20)	*P*
	mean ± SD	mean ± SD	mean ± SD	mean ± SD	
Volume of maxillary sinus	21.7 ± 7.8	24.9 ± 7.7	21.2 ± 7.3	23.1 ± 5.8	0.22
Sphenoid Diameter (mm)	36.5 ± 9.8	40.0 ± 6.5	38.1 ± 8.9	41.2 ± 9.6	0.41

Table 4. Relationship of TBHP grades with subjective tinnitus

Finding		Grade 1 (n=10)		Grade 2 (n=25)		Grade 3 (n=43)		Grade 4 (n=18)		*P*
		%	No.	%	No.	%	No.	%	No.	
Tinnitus	Yes	0	0.0	0	0.0	18	41.9	13	72.2	**< 0.001**
	No	10	100.0	25	100.0	25	58.1	5	27.8	

Results

Tinnitus was present in 31 study cases (32.3%) in patients with TBHP and 8 (8%) of controls, i.e. there was a 5.5-fold increase in the likelihood of subjective tinnitus in cases (HP group) compared to the control group with odds ratio (OR) of 5.48, P<0.001), as shown in Table 1.

Sinusitis was reported in 8 study cases (8%) and 5 controls (5%). This difference was not statistically significant, (P>0.05). Table 2 depicts the relationship between TBHP grading and demographic characteristics of patients.

Concha bullosa was significantly more frequent in study patients with positive history of tinnitus (10 cases; 10%) than in controls (0.0%), (P=0.002).

Mean volume of maxillary sinus in study cases was 22.6 ± 7.2 compared to 12.8 ± 4.4 for controls, indicating larger maxillary sinus volume in study cases compared with controls, (P<0.001). Regarding sphenoid sinus diameter, the mean was 39.0 ± 8.6 mm in study cases vs. 30.7 ± 4.9 in controls, which was statistically significant (P< 0.001).

The distribution of patients according to grades of HP is shown in Figure 6, where grade 1 was found in 10 patients (10%), grade 2 in 25 patients (25%), grade 3 in 45 patients (45%) and grade 4 in 20 patients (20%). There were no patients with grade 5 HP in this study.

Data in Table 3 show no significant differences either in the volume of maxillary sinus or in sphenoid diameter among study patients with different HP grades (P>0.05).

Tinnitus was more frequent with higher grade pneumatization. None of the study patients with grade 1 and grade 2 HP reported tinnitus, 41.9% of the patients with grade 3 and 72.2% of those with grade 4 had tinnitus, (P<0.001), as shown in Table 4 and Figure 7.

No significant relationship was found between anterior grading of TBHP with otomastoiditis, sinusitis or with concha bullosa, (P>0.05), as shown in Table 5. Further analysis for the relationship between grading of anterior HP and posterior extension of temporal bone air cells beyond the sigmoid sinus showed that this posterior extension is present with nearly all cases of anterior HP, but the degree of posterior extension was more frequently seen with advanced anterior grading. All patients with grade 1 and grade 2 had an extension of <10 mm, whereas 44.4% of those with grade 3 and all those with grade 4 had an extension of 10 – 20 mm, (P<0.001), as shown in Table 6 and Figure 8.

Figure 6. Distribution of grading among HP cases (N=100).

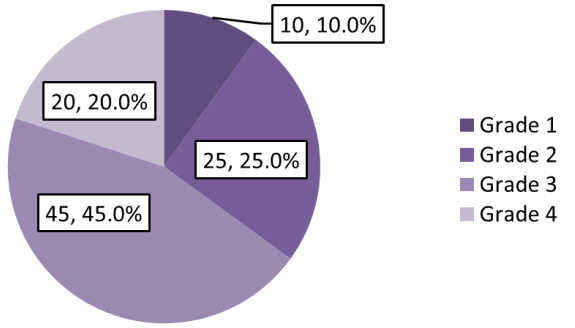
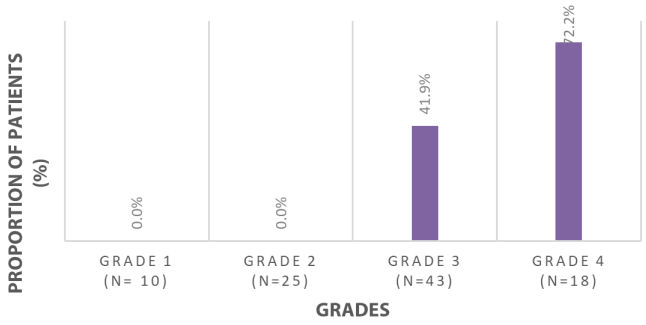


Figure 7. Distribution of tinnitus according to grading (N=96).



Discussion

Tinnitus is the perception of sound in the absence of physical sound. The sound can be in the form of buzzing, ringing, or whistling. It is classified as subjective tinnitus when it is heard only by the patient (non-auscultable), and objective tinnitus when heard by others apart from the patient (auscultable)

Figure 8. Proportional distribution of posterior extension beyond sigmoid sinus according to HP grading.

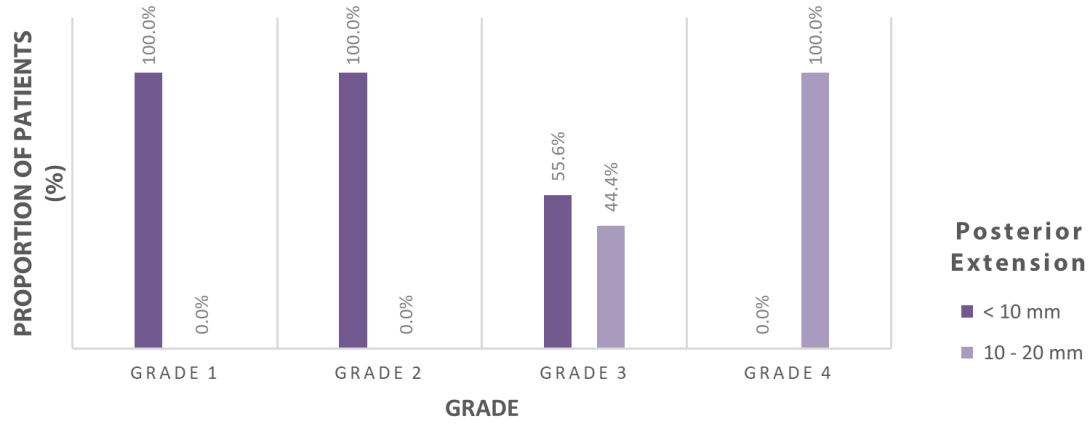


Table 5. Relationship of grading with radiological findings of patients.

Finding		Grade 1 (n=10)		Grade 2 (n=25)		Grade 3 (n=45)		Grade 4 (n=20)		*P*
		%	No.	%	No.	%	No.	%	No.	
Otomastoiditis	Yes	0	0.0	0	0.0	2	4.4	2	10.0	0.34
	No	10	100.0	25	100.0	43	95.6	18	90.0	
Sinusitis	Yes	1	10.0	1	4.0	4	8.9	2	10.0	0.84
	No	9	90.0	24	96.0	41	91.1	18	90.0	
Concha	Yes	1	10.0	3	12.0	4	8.9	2	10.0	0.98
	No	9	90.0	22	88.0	41	91.1	18	90.0	

Table 6. Relationship between grading of TBHP and posterior extension beyond the sigmoid sinus among cases (N=100).

Posterior extension	Grade 1 (n=10)		Grade 2 (n=25)		Grade 3 (n=45)		Grade 4 (n=20)		*P*
	No.	%	No.	%	No.	%	No.	%	
< 10 mm	10	100.0	**25**	100.0	**25**	55.6	**0**	0.0	**< 0.001**
10 – 20 mm	0	0.0	**0**	0.0	**20**	44.4	**20**	100.0	

(1,10). TBHP may be attributed as one of the possible etiological factors for the development of tinnitus (2).

Although TBHP is commonly observed on the CT studies, its description is generally not included in the radiological reports. It is regarded as a normal anatomical variation of little or no clinical significance. However, previous reports, and our observation that TBHP is found in many patients complaining of unexplained tinnitus, formed the basis of this study. The relationship between TBHP and tinnitus has been discussed in the literature (1,11). Scientific papers on the topic of hyper-pneumatization of temporal bone (3,5), extensive pneumatization (12) and over-pneumatization (13) have graded the aeration of temporal bone extending beyond the normal confines of the mastoid region.

This study demonstrates statistically significant correlation of ST with TBHP, and the correlation of a higher prevalence of ST with higher grades of TBHP.

The occurrence of ST in patients with TBHP is attributed to the presence of excessive air cells between the horizontal petrous part of ICA and the cochlea, as the blood flow in the internal carotid artery (ICA) is transmitted and amplified by these air cells, and received by the cochlea.

Sözen et al. (11) found that TBHP was seen in 17 patients out of 25 patients presented with ST (i.e. 68 %). These authors also postulated that conduction of the vibrations occurring in the wall of ICA to the perilymph and endolymph can lead to ST (11).

Tüz et al. (12) suggested that diffuse osteoporosis around the ICA in elderly patients can lead to subjective tinnitus due to decreased insulation.

In this study, we found that there is no statistically significant correlation between the age and gender of the patients and prevalence of TBHP. This is in agreement with the findings of Virapongse et al. (14), who suggested that squamo-mastoid pneumatization follows the classic normal distribution and does not depend upon age or gender.

We found a high degree of bilateral TBHP (95%); similarly, Virapongse et al. (14) found 72-99% symmetry in pneumatization in the general population.

We found that all cases with anterior TBHP had concomitant posterior extension around the sigmoid sinus plate. There is statistically significant correlation between the degrees of anterior pneumatization based on grading and the extent of posterior extension beyond the confines of sigmoid sinus. The degree of posterior extension was higher with increasing grades of anterior extension. We did not find a statistically significant correlation between extent of pneumatization based on this grading system with any of the following parameters: age, gender, laterality or distribution of pneumatization, maxillary sinus volume (MSV), sphenoidal sinus axial diameter (SAD) or presence/absence of infection.

As stated before, subjective tinnitus (ST) was found to be more frequent with advancing grades of TBHP in our study cases.

In this study, the volume of maxillary sinus and the axial diameter of sphenoid sinus showed a statistically significant increment in patients with HP when compared with the control group.

Hindi et al. (7) studied HP of sphenoid and ethmoid sinuses according to their anatomical extension and the presence of normal anatomical variants of air cells (namely, Aggernasi cells, Haller cells and Onodi cells) in correlation with mastoid over-pneumatization, and they found a positive correlation between the two. This group also noticed that the post-sellar type of sphenoid sinus pneumatization was the most predominant type (83.3%) in the well-pneumatized mastoid, whereas the pre-sellar type of sphenoid sinus was seen in only 16.7% in the well-pneumatized mastoid (7).

In this study, we found a statistically significant correlation between TBHP with presence of CB. However, its presence showed no statistically significant correlation with increasing grade of TBHP. Hindi et al. (7) also found that prevalence of concha bullosa was significantly higher among patients with excessive pneumatization of temporal bone, as in our study.

Prevalence of chronic paranasal sinusitis among the TBHP group was not significantly different from that among the control group. Furthermore, there was no significant correlation between presence of chronic paranasal sinusitis with increasing grade of TBHP. This may suggest that size or degree of PNS pneumatization does not play a significant role in pathogenesis of chronic sinusitis. This observation is in agreement with the findings of Chang et al (15).

Otomastoiditis was found in 4 (4%) HP group patients and none (0%) of the controls; however, this difference was not statistically significant. Neither was there statistically significant correlation between the presence of otomastoiditis and increasing grades of TBHP.

Conclusion

There is a statistically significant association of subjective tinnitus with the presence and increasing grade of TBHP. TBHP is also associated with paranasal sinus hyperpneumatization, and increased occurrence of concha bullosa, whereas there is no statistically significant association between TBHP and development of chronic sinusitis and otomastoiditis. This report confirms the findings of previous studies and adds to experience that can help in diagnosis, management and prognostication inpatients with clinical tinnitus and sinusitis.

Conflict of interest

The authors report no conflict of interest.

References

1. Topal O, Erbek SS, Erbek S, Ozluoglu LN. Subjective pulsatile tinnitus associated with extensive pneumatization of temporal bone. Eur Arch Otorhinolaryngol. 2008 Jan 1;265(1):123-5.

2. Vattoth S, Shah R, Curé JK. A compartment-based approach for the imaging evaluation of tinnitus. AJNR Am J Neuroradiol. 2010 Feb 1;31(2):211-8.

3. Houet EJ, Kouokam, LM, Nchimi Longang, A. Images in clinical radiology: Skull base bone hyperpneumatization. JBR–BTR. 2013;96.

4. Drake RL, Vogl AW, Mitchell A, Tibbitts R, Richardson P. Gray's Atlas of Anatomy.1st ed. London: Churchill Livingstone; 2007 Aug.

5. Littrell LA, Leutmer PH, Lane JI, Driscoll CL. Progressive calvarial and upper cervical pneumatization associated with habitual valsalva maneuver in a 70-year-old man. AJNR Am J Neuroradiol. 2004 Mar 1;25(3):491-3.

6. Adam A, Dixon A, Gillard J, Schaefer-Prokop C, Grainger G. Grainger & Allison's Diagnostic Radiology. 6th ed. London: Churchill Livingstone; 2014 Jun.

7. Hindi K, Alazzawi S, Raman R, Prepageran N, Rahmat K. Pneumatization of mastoid air cells, temporal bone, ethmoid and sphenoid sinuses. Any correlation?. Indian J Otolaryngol Head Neck Surg. 2014 Dec 1;66(4):429-36.

8. Han SJ, Song MH, Kim J, Lee WS, Lee HK. Classification of temporal bone pneumatization based on sigmoid sinus using computed tomography. Clin Radiol. 2007 Nov 30;62(11):1110-8.

9. Jasim HH, Al-Taei JA. Computed tomographic measurement of maxillary sinus volume and dimension in correlation to the age and gender (comparative study among individuals with dentate and edentulous maxilla). JBCD. 2013;25(1):87-93.

10. Weissman JL, Hirsch BE. Imaging of tinnitus: a review. Radiology. 2000 Aug;216(2):342-9.

11. Sözen E, Çelebi I, Uçal YO, Coskun BU. Is there a relationship between subjective pulsatile tinnitus and petrous bone pneumatization?. J Craniofac Surg. 2013 Mar 1;24(2):461-3.

12. Tüz M, Doğru H, Yeşildağ A. Subjective pulsatile tinnitus associated with extensive pneumatization of temporal bone. Auris Nasus Larynx. 2003 May 15;30(2):183-5.

13. Beek E, Smithuis R. Temporal bone – Anatomy [Internet]. Leiderdorp, the Netherlands: Radiology Assistant; c2006 Jul 15 [updated 2007 Feb 21; cited 2017 May 17]. Available from: http://www.radiologyassistant.nl/en/p43facba0911f5/temporal-bone-anatomy.html. www.radiologyassistant.com

14. Virapongse C, Sarwar M, Bhimani S, Sasaki C, Shapiro R. Computed tomography of temporal bone pneumatization: 1. Normal pattern and morphology. AJR Am J Roentgenol. 1985 Sep 1;145(3):473-81.

15. Chang CC, Incaudo GA, Gershwin ME, editors. Diseases of the sinuses: a comprehensive textbook of diagnosis and treatment. Springer; 2014 Jun 6.