ARTICLE IN PRESS

The Egyptian Journal of Radiology and Nuclear Medicine xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

The Egyptian Journal of Radiology and Nuclear Medicine

journal homepage: www.elsevier.com/locate/ejrnm

Original Article

CT evaluation of pterygoid process pneumatization and the anatomic variations of related neural structures☆

Mohamad Hasan Alam-Eldeen[a,*], Mostafa A. ElTaher[b], Khaled Nasser Fadle[c]

[a] Department of Diagnostic Radiology, Sohag Faculty of Medicine, Sohag University, Egypt
[b] Department of ENT, Sohag Faculty of Medicine, Sohag University, Egypt
[c] Department of Neurosurgery, Sohag Faculty of Medicine, Sohag University, Egypt

ARTICLE INFO

Keywords:
Pterygoid process
Vidian canal
Foramen rotundum
CT

ABSTRACT

Objective: This topic is concerned with the clarification of the radiological findings that should be reported as regard the anatomic variations of the neural structures related to the pterygoid process in patients listed for endoscopic sinus surgery.

Materials and methods: This retrospective study included 164 patients who underwent multislice CT scan on paranasal sinuses in the Diagnostic Radiology Department in the period from February 2017 to December 2017. The pattern of pterygoid process pneumatization was evaluated. The anatomic variations of related neural structures were recorded.

Results: The study included 164 patients with 328 pterygoid processes. The process was unpneumatized in 38.4% and pneumatized in 61.6%. Vidian canal type 1 was found in 7.3%, type 2 in 61.6% and type 3 in 31.1%. The incidence of foramen rotundum protrusion was higher with pneumatized processes, yet no statistically significant association was found.

Conclusion: The neural structures related to the pterygoid process are the seat of many anatomic variations that need to be identified by preoperative CT.

1. Introduction

Being less invasive, endoscopic surgery is commonly used nowadays for the treatment of many paranasal sinuses (PNS) diseases [1]. Surgical excision of pituitary tumors is also commonly performed via endoscopic transsphenoidal approach [2]. The sinuses are the seat of many anatomical variations. Proper identification of these variations prior to surgery using CT is essential to minimize the incidence of complications and to avoid the risk of injury of important structures [3]. Many vital anatomical structures are related to the sphenoid sinus including vidian canal (VC) and foramen rotundum (FR) [4]. The sphenoid bone is formed of body, lesser and greater wings and paired pterygoid process (PP) [5]. The medial and lateral PP are caudal perpendicular extension from the sphenoid sinus body. The PP base is formed by the fusion of the anterosuperior extensions of the medial and lateral processes. The processes are related to the infratemporal fossa laterally, the pterygopalatine fossa anteriorly, the eustachian tube, petro-occipital fissure, petro-sphenoidal fissure and internal carotid artery canal posteriorly and posterolaterally, and to the middle cranial fossa superiorly [6,7]. The pterygopalatine fossa has a communication with the middle cranial fossa, orbit, nasal cavity, oral cavity, pharynx, foramen lacerum and with the infratemporal fossa. The VC connects pterygopalatine fossa with the foramen lacerum. The FR lies superolateral to the VC and it connects the pterygopalatine fossa with the middle cranial fossa [8]. The sphenoid sinus usually attains its mature size by the age of fourteen [9]. The sphenoid sinus and the PP are liable to variable degrees of pneumatization [10,11]. Also, they are part of the maxillofacial structures that can be affected by systemic osseous diseases such as renal osteodystrophy [12]. The pneumatization of the PP commonly alters the position of the VC [4]. According to its relation to the body of sphenoid sinus, the VC was classified into three types: canal protruding into sphenoid sinus cavity (type 1), canal lying at the sphenoid sinus floor with or without little protrusion into its cavity (type 2) or canal totally embedded in sphenoid sinus body (type 3). Dehiscence of the VC roof or of the FR is associated with the risk of injury of vital structures [13]. The variations of the anatomical

Abbreviations: PNS, paranasal sinuses; VC, vidian canal; FR, foramen rotundum; PP, pterygoid process

☆ This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
Peer review under responsibility of The Egyptian Society of Radiology and Nuclear Medicine.

* Corresponding author at: Department of Diagnostic Radiology, Sohag Faculty of Medicine, Sohag University, Egypt.
E-mail address: m.elkousy@yahoo.com (M. Hasan Alam-Eldeen).

https://doi.org/10.1016/j.ejrnm.2018.03.011
Received 4 February 2018; Accepted 16 March 2018

Please cite this article as: Alam-Eldeen, M.H., The Egyptian Journal of Radiology and Nuclear Medicine (2018), https://doi.org/10.1016/j.ejrnm.2018.03.011

Table 1
Distribution of the pattern of pterygoid process pneumatization.

Pterygoid process	Unilateral	Bilateral	Total
Unpneumatized	46 (14%)	80 (24.4%)	126 (38.4%)
Pneumatized	46 (14%)	156 (47.6%)	202 (61.6%)
			328 (100%)

structures related to the sphenoid sinus are commonly hidden during endoscopic surgery by many underlying diseases such as mucocele or masses, a situation that necessitates accurate clarification by pre-operative CT [9].

2. Materials and methods

This retrospective study included 164 patients who were referred for CT scan on PNS from the ENT Department or from the outpatient clinic to the Diagnostic Radiology Department in the period from February 2017 to December 2017. Patients with previous sinus surgery and patients younger than 16 years were excluded from the study to guarantee that the sphenoid sinus attained full maturation.

CT scans were performed using GE Lightspeed ultra 8 slice CT scanner and Toshiba Alexion 16 slice CT scanner. Axial scans were obtained with 0.5 mm slice thickness in a plane parallel to the hard palate. Coronal reformatted images were obtained using a dedicated workstations.

Approval of our institute Research Ethics Committee was obtained.

2.1. Image analysis

Coronal images were reviewed to evaluate pneumatization of the sphenoid sinus and PP, position of VC and FR in relation to the sphenoid sinus, and for the presence of bony dehiscence of the canal or of the foramen. PNS were also evaluated for the presence of underlying diseases such as sinusitis, polyposis or masses and for any associated erosion of the canal or of the foramen.

Protrusion of the VC or FR is considered when a part of their margins is surrounded by air in at least one coronal scan [2].

2.2. Statistical analysis

The results obtained were statistically analyzed with the help of statistical package for social sciences (2007 SPSS 16.0 for windows) for statistical analysis. Values less than 0.05 were accepted as statistically significant.

3. Results

The study included 164 patients, 104 males (63.4%) and 60 females (36.6%) with 328 PP, VC and FR. They ranged in age between 19 and 68 years with the mean age was 33.5 years.

Of the 328 PP included in the study, 126 processes were unpneumatized (38.4%); unilateral in 46 (14%) and bilateral in 80 (24.4%); whereas 202 processes were pneumatized (61.6%); unilateral in 46 (14%) and bilateral in 156 (47.6%); (including pneumatized processes that were involved by an underlying sinus pathology such as sinusitis) (Table 1) (Fig. 1). We had 60 females with 120 PP in our study, it was unpneumatized in 53 (44.2%) and pneumatized in 67 (55.8%). We had 104 males with 208 PP in our study, it was unpneumatized in 73 (35.1%) and pneumatized in 135 (64.9%). No significant gender predilection was found in our study, $p = 0.124$.

In the 202 pneumatized PP, type 1 VC was found in 24 (11.9%), type 2 in 164 (81.2%) and type 3 in 14 (6.9%). Consequently type 1 and type 2 were found in 93.1%.

In the 126 unpneumatized PP, type 2 VC was found in 38 (30.2%),

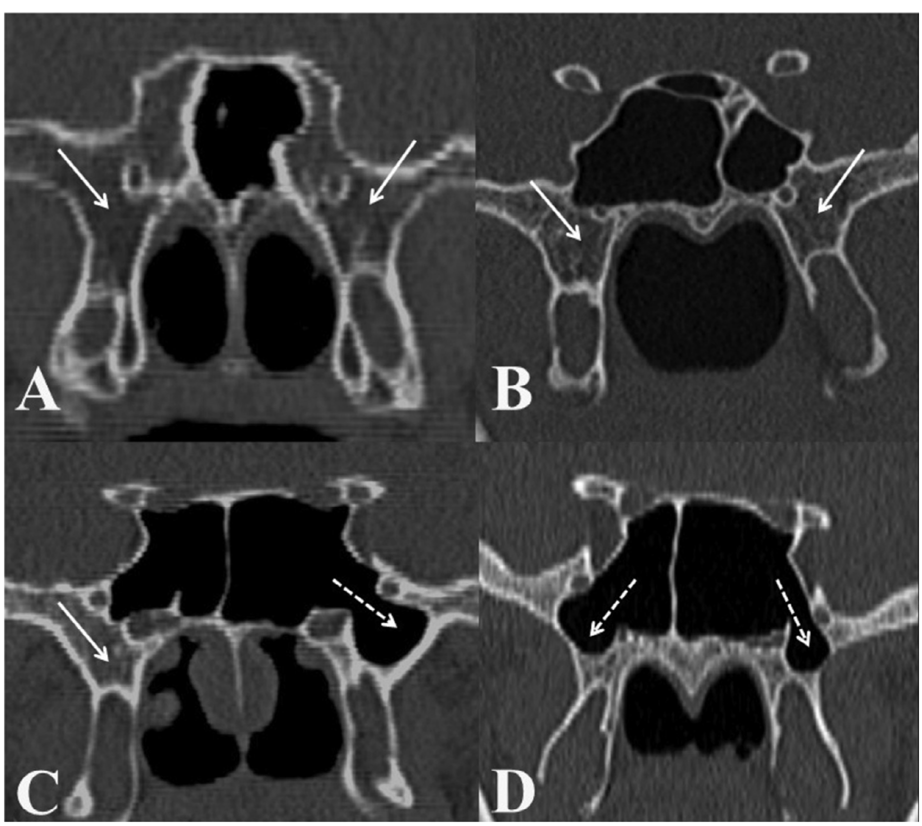

Fig. 1. Patterns of pterygoid process pneumatization. A&B. Bilateral unpneumatized process. C. Pneumatized Lt and unpneumatized Rt process. D. Bilateral pneumatized process. Solid arrow points to unpneumatized process while dashed arrow points to pneumatized process.

Table 2
State of pterygoid process pneumatization and type of vidian canal.

Vidian canal	Pneumatized process	Unpneumatized process
Type 1	24 (11.9%)	0
Type 2	164 (81.2%)	38 (30.2%)
Type 3	14 (6.9%)	88 (69.8%)
Total	202 (100%)	126 (100%)

Table 3
Incidence of vidian canals types in the study.

Vidian canal type	Pneumatized and unpneumatized process
Type 1	24 (7.3%)
Type 2	202 (61.6%)
Type 3	102 (31.1%)
Total	328 (100%)

type 3 in 88 (69.8%) whereas type 1 was not found (Table 2). Consequently type 1 and type 2 were found in 38.2%. Our results revealed that type 1 and type 2 had strong association with PP pneumatization (p = 0.007).

In the 328 PP, VC type 1 was found in 24 (7.3%), type 2 in 202 (61.6%) and type 3 in 102 (31.1%) (Table 3) (Fig. 2). Dehiscence of VC bony roof was found in 4 (1.2%), unilateral type 2 in 2, unilateral type 1 in 1, Rt type 2 and Lt type 1 in 1 and was associated with dehiscent Rt FR. They were associated with pneumatized process in 3 and with unpneumatized process in 1 (Fig. 3).

In the 202 pneumatized PP, unilateral protrusion of FR into sinus cavity was found in 43 (21.3%), separation from the sinus cavity by a thin bony plate in 12 (5.9%) and dehiscence in 3 (1.5%) whereas in the 126 unpneumatized processes, unilateral protrusion was found in 19 (15.1%) separation from the sinus cavity by a thin bony plate in 6 (4.8%) and dehiscence in 2 (1.6%) (Table 4) (Figs. 2D, 3A, 4). The incidence of FR protrusion was higher in case of pneumatized process, yet no statistically significant association was found (p = 0.238).

In the 164 patients included in the study, sinusitis was found in 98 patients (59.8%), polyposis in 24 (14.6%), mucocele in 14 (8.5%), fibrous dysplasia in 2 (1.2%) whereas 26 where free (15.9%). Fungal sinusitis was found in 23 of the 98 patients with sinusitis and was found in 5 of the 24 patients with polyposis. Erosion of FR was found in 1 patient with fungal sinusitis on top of polyposis (Fig. 5).

4. Discussion

The sphenoid sinus and PP are the seat of variable degrees of pneumatization that are commonly associated with anatomic variations of the closely related neural structures [11,14]. These neural structures are separable from the sinus by thin bones [2]. Focal dehiscence of the bony margin of the neural structures is associated with the risk of operative injury [15]. Furthermore, many underlying sinus diseases may destruct the sinus walls and involve the related neural structures [16,17]. The role of CT in the assessment of PNS is well established [18]. The progress in sinus endoscopic surgery necessitates accurate assessment of these variations by preoperative CT to minimize the risk of operative complications [2,19,20].

In our study, the PP was unpneumatized in 38.4% whereas it was pneumatized in 61.6%. Pneumatized processes were unilateral in 14% and bilateral in 47.6%. It was reported that the process was pneumatized in 29.3%, unilateral in 63% and bilateral in 37% [10].

In our study, the process was unpneumatized in 44.2% and pneumatized in 55.8% in females whereas it was unpneumatized in 35.1% and pneumatized in 64.9% in males. No significant gender predilection was found in our study. Our results are in agree with a study that reported no significant gender predilection [1].

In the 328 PP included in our study, VC type 1 was found in 7.3%, type 2 in 61.6% and type 3 in 31.1%. Our results are close to a study that found type 1 in 10%, type 2 in 54%, type 3 in 36% [21]. The results of our study differ from other studies, one study reported type 1 in 53.4%, type 2 in 34.2% and type 3 in 12.5% [22], other study reported type 1 in 28%, type 2 in 48% and type 3 in 24% [23], whereas another

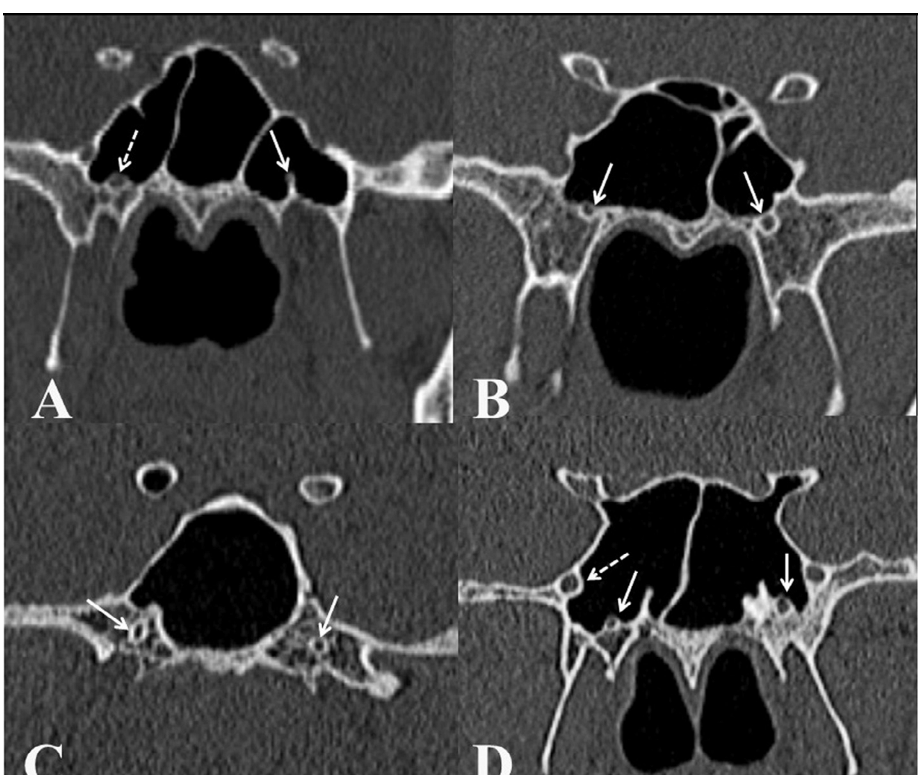

Fig. 2. Types of vidian canals. A. Rt type 2 and Lt type 1, note protrusion of the Rt canal into the floor of sphenoid sinus (dashed arrow). B. Bilateral type 2. C. Bilateral type 3. D. Bilateral type 2, note protrusion of Rt foramen rotundum into sphenoid sinus with preserved bony margin (dashed arrow) and pneumatized Rt pterygoid process.

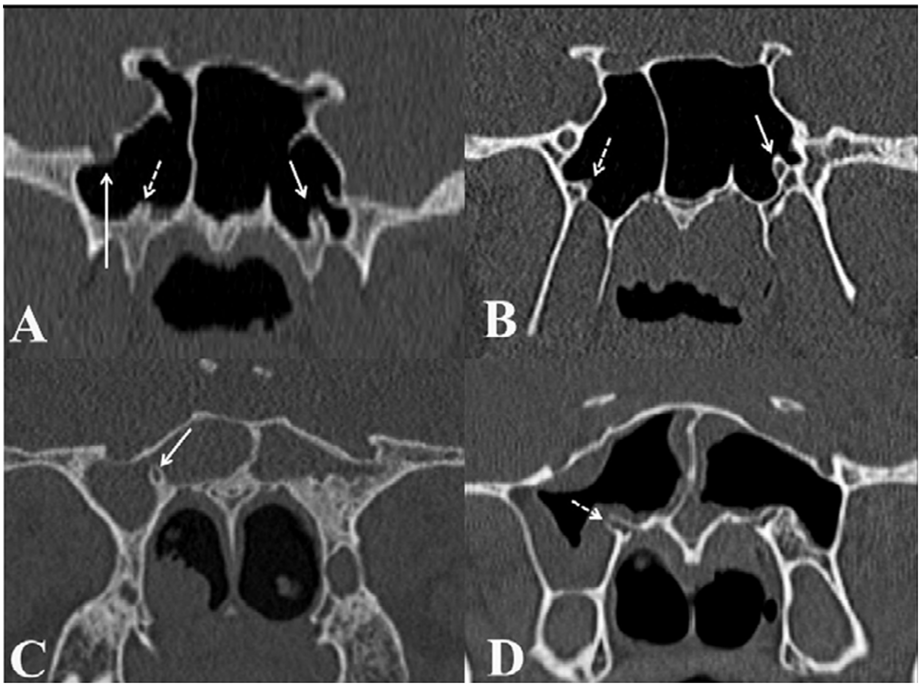

Fig. 3. Vidian canal wall dehiscence. A. Dehiscent Rt type 2 canal (dashed arrow), dehiscent Lt type 1 canal (white arrow) and thin bony plate separating Rt foramen rotundum from sphenoid sinus (long white arrow). B. Dehiscent Rt type 2 canal and non dehiscent Lt type 1 canal. C. Non dehiscent Rt type 1 canal with sphenoidal sinusitis. D. Dehiscent Rt type 1 canal with sphenoidal sinusitis. Note pneumatized pterygoid process with all dehiscent canals.

Table 4
State of pterygoid process pneumatization and foramen rotundum variations.

Foramen rotundum	Pneumatized process	Unpneumatized process
Protrusion	43 (21.3%)	19 (15.1%)
Separation by thin bony plate	12 (5.9%)	6 (4.8%)
Dehiscence	3 (1.5%)	2 (1.6%)
Normal	144 (71.3)	99 (78.5%)
Total	202 (100%)	126 (100%)

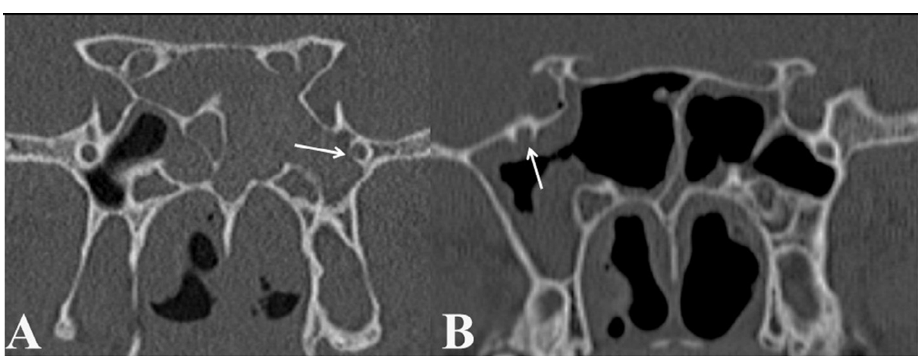

Fig. 4. Dehiscent foramen rotundum. A. Dehiscent Lt foramen with sphenoidal sinusitis. B. Dehiscent Rt foramen with sphenoidal sinusitis. Note pneumatized pterygoid process in both.

study reported type 1 in 35.1%, type 2 in 28.5% and type 3 in 36.4% [1].

Our results revealed a statistically significant association between PP pneumatization and the occurance of type 1 and type 2 VC. Authors reported a strong association between process pneumatization and canal protrusion into sinus cavity [4].

Our study revealed VC bony roof dehiscence in 1.2%. Dehiscence was found in 7.1% in one study [2] whereas it was 37% and 32% in two other studies [21,24].

Our study revealed that in the pneumatized PP group, the FR showed protrusion in 21.3%, separation by a thin bony plate in 5.9% and dehiscence in 1.5% whereas in the unpneumatized process group, it showed protrusion in 15.1%, separation by a thin bony plate in 4.8% and dehiscence in 1.6%. Authors reported dehiscence in 3.5% and separation by thin bone in 14.2% [2]. The incidence of foramen protrusion in our study was higher in case of pneumatized process, yet no statistically significant association was found. However, authors reported a statistically significant correlation between PP pneumatization and FR protrusion [4].

5. Conclusion

The pterygoid process shows variable degrees of pneumatization which are commonly associated with anatomic variations of the adjacent neural structures. Identification of both by preoperative CT is mandatory to avoid the risk of operative injury.

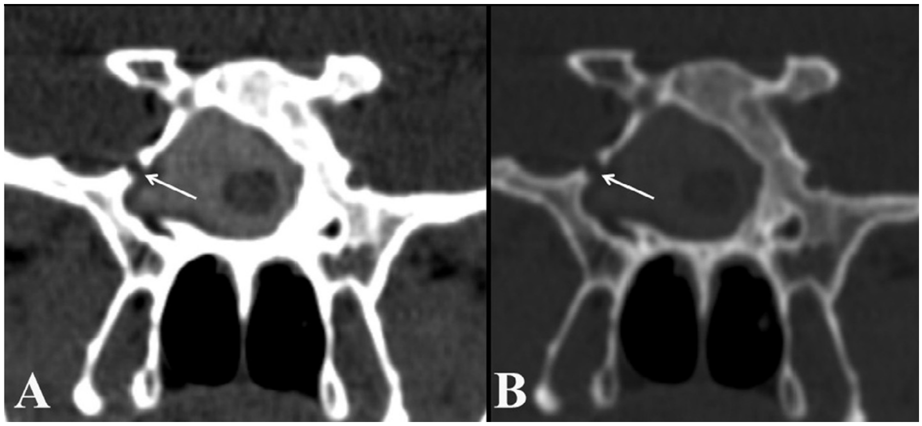

Fig. 5. Rt foramen rotundum erosion in a patient with fungal sinusitis on top of polyposis.

6. Conflict of interest

We have no conflict of interest to disclose.

The authors declare no conflict of interest.

References

[1] Yeğin Y, Çelik M, Altıntaş A, Şimşek BM, Olgun B, Kayhan FT. Vidian canal types and dehiscence of the bony roof of the canal: an anatomical study. Turk Arch Otorhinolaryngol 2017;55:22–6.
[2] Unal B, Bademci G, Bilgili YK, Batay F, Avci E. Risky anatomic variations of sphenoid sinus for surgery. Surg Radiol Anat 2006;28(2):195–201.
[3] Kaplanoglu H, Kaplanoglu V, Dilli A, Toprak U, Hekimoğlu B. An analysis of the anatomic variations of the paranasal sinuses and ethmoid roof using computed tomography. Eurasian J Med 2013;45:115–25.
[4] Kazkayasi M, Karadeniz Y, Arikan OK. Anatomic variations of the sphenoid sinus on computed tomography. Rhinology 2005;43(2):109–14.
[5] Budu V, Mogoanta CA, Fanuta B, Bulescu I. The anatomical relations of the sphenoid sinus and their implications in sphenoid endoscopic surgery. Rom J Morphol Embryol 2013;54(1):13–6.
[6] Kasemsiri P, Solares CA, Carrau RL, Prosser JD, et al. Endoscopic endonasal transpterygoid approaches: anatomical landmarks for planning the surgical corridor. Laryngoscope 2013;123(4):811–5.
[7] Razek AA, Huang BY. Lesions of the petrous apex: classification and findings at CT and MR imaging. Radiographics 2012;32(1):151–73.
[8] Kim HS, Kim DI, Chung LH. High-resolution CT of the pterygopalatine fossa and its communications. Neuroradiology 1996;38:S120–6.
[9] Anusha B, Baharudin A, Philip R, Harvinder S, Shaffie BM. Anatomical variations of the sphenoid sinus and its adjacent structures: a review of existing literature. Surg Radiol Anat 2014;36(5):419–27.
[10] Sirikci A, Bayazõt YA, Bayram M, Mumbuç S, Güngör K, Kanlõkama M. Variations of sphenoid and related structures. Eur. Radiol. 2000;10(5):844–8.
[11] Welker KM, DeLone DR, Lane JI, Gilbertson JR. Arrested pneumatization of the skull base: imaging characteristics. AJR 2008;190(6):1691–6.
[12] Abdel Razek AA. Computed tomography and magnetic resonance imaging of maxillofacial lesions in renal osteodystrophy. J Craniofac Surg 2014;25(4):1354–7.
[13] Lee JC, Kao CH, Hsu CH, Lin YS. Endoscopic transsphenoidal vidian neurectomy. Eur Arch Otorhinolaryngol 2011;268:851–6.
[14] Cheung DK, Attia EL, Kirkpatrick DA, Marcarian B, Wright B. An anatomic and CT scan study of the lateral wall of the sphenoid sinus as related to the transnasal transethmoid endoscopic approach. J Otolaryngol 1993;22(2):63–8.
[15] Hoang JK, Eastwood JD, Tebbit CL, Glastonbury CM. Multiplanar sinus CT: a systematic approach to imaging before functional endoscopic sinus surgery. AJR 2010;194(6):w527–36.
[16] Chapman PR, Shah R, Cure JK, Bag AK. Petrous apex lesions: pictorial review. AJR 2011;196(3 suppl):ws26–37.
[17] Momeni AK, Roberts CC, Chew FS. Imaging of chronic and exotic sinonasal disease: review. AJR 2007;189(6 suppl):s35–45.
[18] Badia L, Lund VJ, Wei W, Ho WK. Ethnic variation in sinonasal anatomy on CT-scanning. Rhinology 2005;43(3):210–4.
[19] Elwany S, Elsaeid I, Thabet H. Endoscopic anatomy of sphenoid sinus. J Laryngol Otol 1999;113(2):122–6.
[20] Hudgins PA. Complications of endoscopic sinus surgery. The role of the radiologist in prevention. Radiol Clin North Am 1993;31(1):21–32.
[21] Yazar F, Cankal F, Haholu A, Kilic C, Tekdemir I. CT evaluation of the vidian canal localization. Clin Anat 2007;20(7):751–4.
[22] Liu SC, Wang HW, Su WF. Endoscopic vidian neurectomy: the value of preoperative computed tomographic guidance. Arch Otolaryngol Head Neck Surg 2010;136(6):595–602.
[23] Mohebbi A, Rajaeih S, Safdarian M, Omidian P. The sphenoid sinus, foramen rotundum and vidian canal: a radiological study of anatomical relationships. Braz J Otorhinolaryngol 2017;83(4):381–7.
[24] Hewaidi G, Omami G. Anatomic variation of sphenoid sinus and related structures in Libyan population: CT scan study. Libyan J Med 2008;3(3):128–33.