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ORIGINAL ARTICLE

Sphenoid Sinus Pneumatization Types and Correlation with Adjacent Neurovascular Structures Using Cone-Beam Computed Tomography

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Abstract

Aims: This study aimed to assess the sphenoid sinus pneumatization types and their correlation with adjacent neurovascular structures using cone-beam computed tomography (CBCT). **Materials and methods:** This cross-sectional study was conducted on 97 CBCT scans of patients over 18 years of age that were retrieved from the archives of the Oral & Maxillofacial Radiology Department of School of Dentistry. Type of sphenoid sinus pneumatization based on its relationship with sella turcica (conchal, presellar, sellar, and postsellar), the correlation of internal carotid artery (ICA) and optic nerve (ON) with the sinus cavity in the axial and coronal planes (smooth or prolonged type), and presence of Onodi cells and their correlation with the sphenoid sinus (lateral, superior, and superolateral) were all evaluated on CBCT sections. Data were analyzed by the Chi-square and Fisher's exact tests (alpha = 0.05). **Results:** Postsellar type was the most common sphenoid sinus pneumatization type (82.5%). The Smooth type was the most common form of correlation of ON and ICA with the sphenoid sinus. Onodi cells were noted in 28.9% of the cases; among which, the lateral type had the highest prevalence. **Conclusion:** Considering the high prevalence of sphenoid sinus pneumatization, Onodi cells, and ON and ICA protrusion in our study population, CBCT should be requested prior to trans-sphenoidal surgical procedures to prevent perioperative and postoperative complications.

Keywords Sphenoid Sinus · Optic Nerve · Internal Carotid Artery · Cone-Beam Computed Tomography

Introduction

The sphenoid sinus has the highest rate of anatomical variations among different sinuses in the human body. Such a high rate of anatomical variations is due to different sphenoid sinus pneumatization types, which complicate surgical procedures in this region [1–5]. Precise preoperative assessment of the sphenoid sinus anatomy and its borders is highly important to enhance surgical access to the pituitary fossa and decrease postoperative complications [6]. Also, adequate knowledge about the size and degree of sphenoid sinus pneumatization is an important prerequisite for its effective treatment [7]. Thus, degree of sinus pneumatization plays an important role in surgical treatment planning. Degree of sphenoid sinus pneumatization is often determined based on the location of posterior sinus wall in relation to the sella turcica. Accordingly, it is divided into four types; conchal, presellar, sellar, and postsellar [1].

Currently, endoscopic surgery is an acceptable approach for the treatment of sinus complications and adenoma of the pituitary gland. However, it is a high-risk procedure since the sphenoid sinus is surrounded by several critical anatomical structures including the optic nerve (ON) and internal carotid artery (ICA) [1, 8]. Thus, transsphenoidal endoscopic surgery is associated with serious risks compared to functional endoscopic sinus surgery. However, knowledge about the anatomy of the sphenoid sinus can decrease the rate of complications of endoscopic sphenoid sinus surgery and trans-sphenoidal procedures [4].

The Sphenoid sinus is the most inaccessible paranasal sinus located in the skull. Its adjacent critical anatomical

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structures including the ON and ICA may be too close to the sinus, resulting in excessive thinning or absence of the bony wall surrounding these critical structures. Thus, ON and ICA may be traumatized in the process of endoscopic surgery. Thus, knowledge about the anatomical position of the sphenoid sinus is imperative to minimize iatrogenic complications [1, 4].

Onodi cells were first described by Dr. Adolph Onodi in early 1900, as the most posterior ethmoidal sinus air cells with superior-lateral extension to the sphenoid sinus [9]. Onodi cells have a variable prevalence rate ranging from 3.5 to 51% [10]. Detection of Onodi cells decreases the risk of damage to the adjacent anatomical structures during endoscopic sinus surgery [11]. A close correlation exists between the Onodi cells and ON, and their detection can significantly decrease the risk of perioperative traumatization of the adjacent structures particularly the ON [9–12].

Cone-beam computed tomography (CBCT) is a precise imaging modality for assessment of the head and neck region and paranasal sinuses. The submillimeter resolution of CBCT especially bony structures for preoperative assessments has been well documented [1–3]. Also, CBCT has lower exposure dose than computed tomography (CT) and is a suitable imaging modality for assessment of the anatomical variations of the sphenoid sinus and Onodi cells [4]. Although the Multidetector computed tomography (MDCT) modality is still the number one choice of many surgeons and use as standard preoperative imaging, CBCT due to mentioned advantages can also be helpful and a useful replacement for CT scans.

Considering the critical location of the sphenoid sinus in the cranial fossa and its critical adjacent structures such as ON and ICA, assessment of sphenoid sinus pneumatization in different populations is important to prevent perioperative complications. Considering the availability of limited studies on this topic with the use of CBCT, this study aimed to assess the sphenoid sinus pneumatization types and correlation with adjacent neurovascular structures using CBCT. Moreover, no study, to the best of the researchers' knowledge, has evaluated this crucial facial key point with CBCT in Isfahan city, Iran.

Methods

This cross-sectional study was conducted on 97 CBCT scans retrieved from the archives of the Oral & maxillofacial Radiology Department of School of Dentistry in 2020–2021. The CBCT scans had been requested for purposes not related to this study, such as third molar extraction, or orthognathic or implant surgery. This study was conducted retrospectively from data obtained for clinical purposes and it is in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the ethics committee of the university (IR.IAU.KHUISF.REC.1400.221). The sample size was calculated to be 97 assuming alpha = 0.05, accuracy of 0.1, and prevalence of sphenoid sinus pneumatization to be 0.5%. The inclusion criteria were high-quality CBCT scans of patients over 18 years, allowing assessment of base of skull, and paranasal sinus walls, as well as ON and ICA in the field of view.

The exclusion criteria were developmental and congenital anomalies, history of previous surgery in the base of skull or paranasal sinuses, infection or severe inflammation of the sinus, mucosal thickening of the sinus (since it would complicate precise assessment of sinus walls), and history of trauma to the base of skull or fracture of this region.

Eligible CBCT scans were selected by convenience sampling. All CBCT scans had been taken with Galileos-Sirona CBCT scanner (Bensheim, Germany) with the exposure settings of 85 kVp, 10–42 mA, and 14 s time, and were analyzed with Sirona Sidexis XG software.

Assessment of sinus pneumatization based on its correlation with sella turcica was conducted on the sagittal CBCT sections. To identify the sella turcica borders, two lines were drawn passing from the most prominent anterior and posterior points of the sella turcica.

The relationship of sphenoid sinus and sella turcica was categorized into four types:

Type 1: Conchal. In this type, the sinus is missing or has minimal extension.

Type 2: Presellar. In this type, the most posterior border of the sphenoid sinus is located in front of the anterior wall of the sella turcica.

Type 3: Sellar. In this type, sphenoid sinus is located between the anterior and posterior walls of the sella turcica.

Type 4: Postsellar. In this type, the posterior sinus wall exceeds beyond the posterior wall of the sella turcica. This type has two subtypes:

(A) The sinus does not extend to the posterior clinoid process, and the posterior clinoid process is not within the pneumatization area.
(B) The posterior clinoid process is in the pneumatization area.

Moreover, the correlation of ICA and ON with the sinus cavity in the axial and coronal planes were evaluated on CBCT scans with 0.5 mm slice thickness. Depending on the extent of invasion of these structures to the sphenoid sinus cavity, two types can be defined [1]:

Table 1 Prevalence of different types of sphenoid sinus pneumatization based on the correlation of sphenoid sinus with sella-turcica

Type		Number	Percentage
Conchal		0	0.0
Presellar		4	4.1
Sellar		13	13.4
Postsellar	type a	52	53.6
	type b	28	28.9
	Total	80	82.5
Total		97	100.0

Table 2 Prevalence of different types of correlation of ON with sphenoid sinus on the right and left sides

Type		Right side		Left side	
		Number	Percentage	Number	Percentage
Smooth type	Irrelevant	4	4.1	5	5.2
	Touch	48	49.5	51	52.6
	Total	52	53.6	56	57.8
Prolonged type	Less than 50%	40	41.2	34	35.1
	More than 50%	5	5.2	7	7.2
	Total	45	46.4	41	42.3
Total		97	100.0	97	100.0

Table 3 Prevalence of different types of correlation of ICA with the sphenoid sinus on the right and left sides

Type		Right side		Left side	
		Number	Percentage	Number	Percentage
Smooth type	Irrelevant	27	27.8	26	26.8
	Touch	36	37.1	39	40.2
	Total	63	64.9	65	67.0
Prolonged type	Less than 50%	30	30.9	30	30.9
	More than 50%	4	4.1	2	2.1
	Total	34	35.1	32	33.0
Total		97	100.0	97	100.0

1. Smooth type: ICA and ON do not protrude into the sinus cavity. This type has 2 subtypes:

(A) Irrelevant: No correlation exists between these vital structures and the sphenoid sinus, and they are located at a considerable distance from the sphenoid sinus.
(B) Touch: These structures are located close to the sinus but have no protrusion into the sinus.

2. Prolonged type: ICA and ON are protruded into the sinus. This type has two subgroups:

(A) $<50\%$: Protrusion of $<50\%$ of the ICA/ON into the sinus.
(B) $>50\%$: Protrusion of $>50\%$ of the ICA/ON into the sinus.

The presence of Onodi cells was also evaluated in the three orthogonal planes, and their correlation with the sphenoid sinus was categorized into three groups of superolateral, lateral, and superior.

Statistical Analysis Data were analyzed by SPSS version 24 using the Chi-square test and Fisher's exact test at a 0.05 level of significance.

Results

Table 1 presents the prevalence of different types of sphenoid sinus pneumatization based on the correlation of sphenoid sinus with sella-turcica. As shown, postsellar type was the most common sphenoid sinus pneumatization type (82.5%).

Table 2 indicates the prevalence of different types of correlation of ON with the sphenoid sinus on the right and left sides. As indicated, the smooth type was the most common form of correlation of ON with the sphenoid sinus (53.6% on the right and 57.8% on the left side).

Table 3 presents the prevalence of different types of correlation of ICA with the sphenoid sinus on the right and left sides. As shown, the smooth type was the most common form of correlation of ICA with the sphenoid sinus.

Table 4 Prevalence of Onodi cells in the sphenoid sinus

Variable	Category	Number	Percentage
Presence of Onodi cells in the sphenoid sinus	Absent	69	71.1
	Present	28	28.9
	Total	97	100.0
Type of Onodi cells in the sphenoid sinus	Lateral	19	67.9
	Superior	5	17.9
	Suprolateral	4	14.3
	Total	28	100.0

Table 5 Correlation of ON and ICA on the right and left sides

ON type		ICA		Total	Phi	P value
		Smooth type	prolonged type			
ON Right side	Smooth type	43 (44.3%)	9 (9.3%)	52 (53.6%)	0.400	< 0.001
	Prolonged type	20 (20.6%)	25 (25.8%)	45 (46.4%)		
	Total	63 (64.9%)	34 (35.1%)	97 (100.0%)	-	-
ON Left side	Smooth type	47 (48.5%)	9 (9.3%)	56 (57.7%)	0.421	< 0.001
	Prolonged type	18 (18.6%)	23 (23.7%)	41 (42.3%)		
	Total	65 (67.0%)	32 (33.0%)	97 (100.0%)	-	-

Table 4 shows the prevalence of Onodi cells in the sphenoid sinus. As indicated, Onodi cells were noted in 28.9% of the cases; among which, the lateral type had the highest prevalence.

Table 5 indicates the correlation of ON and ICA in the right and left sides. The results showed a significant correlation between the ON and ICA on both the right ($P < 0.001$) and left ($P < 0.001$) sides.

Discussion

This study assessed the sphenoid sinus pneumatization types and correlation with adjacent neurovascular structures using CBCT. The results showed that the conchal type was the least common (0%), and the postsellar type was the most common sphenoid sinus pneumatization type (82.5%) in the present study. Movahhedian et al., [1] in their study on an Iranian population found that conchal type had the lowest, and postsellar type had the highest prevalence in their study population. However, Štoković et al. [2] reported that conchal type was the least common (2%) and sellar type (41%) was the most common type in their study population, and postsellar type had a prevalence of 25% in their study. The prevalence of conchal, presellar, sellar, and postsellar (a) and (b) types was 0.3%, 6.6%, 57.2%, 17.9%, and 17.9%, respectively, in a study by Güldner et al. [3]. According to Rahmati et al., [4] the prevalence of conchal type was 0% while postsellar type was the most prevalent type with a prevalence of 83.5% followed by sellar type (14.6%). The prevalence of presellar, sellar, and postsellar types was 28.2%, 39.4%, and 32.4%, respectively in a study by Refaat and Basha [8]. In a study by Degaga et al., [13] the prevalence of conchal, presellar, sellar, and postsellar types was 2%, 50%, 25.5%, and 25.5%, respectively. According to Bilgir et al., [14] postsellar type had the highest prevalence (57.8%) followed by sellar type (35.9%), presellar type (3.9%), and conchal type (2.3%). In all the above-mentioned studies and the present investigation, conchal type had the lowest prevalence, while the most common type varied among different studies. The present results regarding the most common type being the postsellar type were in agreement with the results of Movahhedian et al., [1] Rahmati et al., [4] and Bilgir et al., [14] probably because all have been conducted on the Iranian population. However, sellar type had the highest prevalence in studies by Štoković et al., [2] and Refaat and Basha [8]. Both postsellar and sellar types (each with a prevalence of 25.5%) were the most common types in the study by Degaga et al. [13]. Controversy in the results can be attributed to racial differences in study populations.

ICA has a direct correlation with the lateral wall of the sphenoid sinus, which increases the risk of perioperative injury. If the surgeon is not aware of the protrusion of ICA, injury to the artery can even lead to fatal hemorrhage. Also, in case of inadequate knowledge about the ON protrusion, it can be damaged perioperatively, which would probably lead to blindness [4]. It has been documented that increased pneumatization of the sphenoid sinus increases the risk of protrusion of adjacent critical structures into the sinus [1–3, 8, 15]. In the present study, correlation of sphenoid sinus with ON was evaluated in the coronal plane, and its correlation with ICA in the axial plane. The results showed that smooth type was the most common form of correlation of ON with the sphenoid sinus (53.6% on the right and 57.8% on the left side). The protrusion of ON into the sphenoid sinus was 4% higher on the right side. The touch subgroup had the highest prevalence on both sides followed by protrusion < 50%. The irrelevant type had the lowest prevalence. In the study by Movahhedian et al., [1] the prevalence of irrelevant, touch, < 50% protrusion, and > 50% protrusion was 49.5%, 56.4%, 18.2%, and 22.2%, respectively. ON protrusion had a prevalence of 33% in the study by Rahmati et al., [4] 31.3% in a study by Unal et al., [6] 4.1% in a study by Kazkayasi et al., [7] 50.6% in the study by Refaat and Basha [8] and 18.5% in a study by Gibelli et al. [16].

Regarding the correlation of ICA with the sphenoid sinus, smooth type was the most common form of correlation of ICA with the sphenoid sinus. The protrusion of ICA into the sphenoid sinus was 2% higher on the right side. The touch-type had the highest prevalence on both sides followed by < 50% protrusion. More than 50% type had the lowest prevalence. In the study by Movahhedian et al., [1] the prevalence of irrelevant, touch, < 50% protrusion, and > 50% protrusion types was 27.6%, 21.5%, 37%, and 13.9%, respectively. The prevalence of ICA protrusion was 38.8% in the study by Rahmati et al., [4] 30.3% in the study by Unal et al., [6] 5.2% in the study by Kazkayasi et al., [7] 47.6% in the study by Refaat and Basha [8] and 13.8% in the study by Gibelli et al. [16]. As shown, wide variability exists in the reported prevalence rates for ON and ICA protrusion in the literature, such that the prevalence of ON protrusion ranges from 4.1 to 50.6%, and the prevalence of ICA protrusion ranges from 5.2 to 47.6%. Such a wide variation may be due to a number of reasons. First of all, no consensus exists in assessment of ON and ICA protrusion. For instance, some authors defined protrusion as pores in the sphenoid sinus air cells with over 50% of the diameter of neurovascular structure; whereas, others did not provide a specific definition for protrusion in their study. Racial differences also affect the size and morphology of the sphenoid sinus, and subsequently the protrusion of ICA and ON [16]. Differences in quality of radiographs may explain the variations in the reported values as well [1].

In the present study, Onodi cells were noted in 28.9% of the cases. The prevalence of Onodi cells was 38.8% in the study by Movahhedian et al., [1] 65.3% in a study by Yanagisawa et al., [10] 7% in a study by Driben et al., [11] 49.5% in a study by Kasemsiri et al., [12] 60% in a study by Than Thanaviratananich et al., [17] 39.8% in a study by Chmielik and Chmielik [18], 1% in the study by Degaga et al., [13] and 49% in a study by Wada et al. [19].

In the current study, the lateral type had the highest prevalence in patients who had Onodi cells (67.9%) followed by the superior type (17.9%). The superior type had the highest prevalence in the study by Movahhedian et al., [1] and the superolateral type had the highest prevalence in the study by Kasemsiri et al. [12]. This controversy can be attributed to racial differences in the study populations as well as different criteria used for detection of Onodi cells. For example, some studies only assessed the axial or coronal CT sections for detection of Onodi cells, which would complicate their detection. It has been demonstrated that the prevalence of Onodi cells would be higher when sagittal CT sections are evaluated, compared with evaluation of axial and coronal sections alone. Assessment of all three orthogonal planes would have higher accuracy for evaluation of the presence of Onodi cells and would yield results comparable to assessments on corpses [1]. In the present study, the axial, sagittal and, coronal sections were evaluated to determine the prevalence of Onodi cells, which was a strength of this study.

The present study also assessed the correlation between ON and ICA protrusion. The results showed a significant correlation between the ON and ICA on both the right ($P < 0.001$) and left ($P < 0.001$) sides. According to Refaat and Basha [8] ON protrusion is always associated with ICA protrusion but ICA protrusion is not always accompanied by ON protrusion. Also, Gibelli et al. [16] stated that ICA and ON protrusions are often correlated.

The limited sample size due to strict eligibility criteria and exclusion of patients with sinus infections, developmental defects, or a history of trauma was limitation of this study. Future studies with a larger sample size on different populations are required. Also, the role of gender and age of patients in sphenoid sinus pneumatization and its types should be assessed in future studies.

Conclusion

Considering the high prevalence of sphenoid sinus pneumatization, Onodi cells, and ON and ICA protrusion in our study population, presurgical imaging is highly recommended. In case of more detailed information especially regarding complex bony structure or shorter scan time and the lower dose required, CBCT imaging could be a useful choice. Therefore, CBCT could be requested, prior to transsphenoidal surgical procedures to prevent perioperative and postoperative complications.

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Declarations

Conflicts of Interest/Competing Interests Not applicable.

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Informed Consent Not applicable.

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