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**ORIGINAL ARTICLE**

# The Sphenoid Sinuses and Anatomical Variations of the Neurovascular Related Structures: A CT Study.

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## ABSTRACT

**Background:** Sphenoid sinuses are surrounded by many crucial structures. During endoscopic sinus surgery or the transsphenoidal procedures, complications as arterial bleeding and visual affection can be caused by nearness of internal carotid artery (ICA) and cranial nerves to sphenoid sinuses. The study aims to study the important structures in sphenoid sinuses and their variations by multi slices computed tomography (MSCT) to guide otorhinolaryngologists to avoid injury of vital structures.

**Methods:** MSCT of paranasal sinuses was done for all included subjects to get fine sphenoid sinuses anatomical details using axial, coronal and sagittal images.

**Results**: Within included 100 adult individuals (200 sphenoid sinuses); we found pneumatization of anterior clinoid process (ACP), pterygoid process (PP), and greater wing of sphenoid (GWS) in 16%, 30%, and 30% of patients. We found protrusion of ICA, optic nerve (ON), MN and V in 40%, 36%, 25% and 28% and their dehiscence in 30%, 31%, 14% and 37%. There was a highly significant relationship between ON protrusion and ACP pneumatization, ICA protrusion and ACP pneumatization, MN protrusion and GWS pneumatization and VN protrusion and PP pneumatization. There were significant associations between GWS pneumatization and MN protrusion and between PP pneumatization and VN protrusion.

**Conclusions:** anatomical sphenoid sinuses variations are usual with high ICA and ON protrusion and dehiscence prevalence. ICA, ON and/or VN protrusion is powerfully related to ipsilateral nearby pneumatization. MN dehiscence and protrusion were less common. Thus, coronal CT is essential in pre-surgical evaluation to minimize vascular and neural injuries.

**Key words:** Sphenoid sinus; CT; Optic nerve; Carotid artery; Endoscopic sinus surgery

## INTRODUCTION

Proper computed tomography (CT) analysis of the paranasal sinuses (PNS) details and their variants is crucial for management plan and intra-operative predilection and it is considered an important step for complete and safe operation peculiarly endoscopic sinus surgery (ESS)[1, 2]. Thus, literature reported many anatomic, endoscopic and radiologic studies that help to supply the surgeon with data for safe ESS [1- 4]. In spite of these literature, post ESS residual lesions and complication continue to happen and is not unusual [5- 6] reflecting the importance of studying this area and highlight its variations especially in the challenging sinus such as the sphenoid sinus.

The sphenoid sinuses are placed at the skull base at the conjunction of the middle and anterior cranial fossae. The relation between the optic nerve (ON) and the paranasal sinuses has been analyzed for nearly a century [7]. **DeLano et al** [8] delineated the precise relations between the ON and the posterior paranasal sinuses using CT data and reported that all the evaluated 300 nerves were closely related to the sphenoidal sinus except a small percent (3%) was in contact with the posterior ethmoidal sinuses. Coronal CT revealed this relationship while the axial scans facilitated visualization of the sphenoethmoidal boundaries. Anatomic configurations that predispose to ON injury include the type 2 or type 3 ON relationship, ON bony dehiscence, and anterior clinoid process (ACP) pneumatization. A pneumatized ACP represents an essential indicator of ON vulnerability resulting from the frequent association with both bony dehiscence and the type 2 or type 3 ON variations [8].

The sphenoid sinuses are the one of the most inaccessible paranasal sinuses and are enclosed by important anatomic structures such as the orbital content, cavernous sinus and internal carotid artery (ICA) and the cranial fossa. Single thin bony plates isolate the sphenoid sinuses from these important structures. Pneumatisation of these sphemoid sinuses irregular spaces scoped between their absences to extended pneumatization [9].

**Mamatha et al** [10] evaluated the frequency of the various anatomical variations of the sphenoid sinuses in relation to transsphenoid sella surgeries and found that the ICA give well defined prominence in the super lateral sphenoid sinus wall in 50% and a bony wall dehiscence in 45% of cases. The whole sella turcica area is made up of pituitary gland, optic chiasma, ICA, cavernous sinus, cranial nerves and sphenoid sinuses [11]. It was suggested that the more the sphenoidal sinus pneumatization, the more ON exposure [8, 12].

The goal of the current work was to study the important structures in the sphenoid sinuses and find the anatomical variations in this area by multi-slices computed tomography (MSCT) in adult to guide otorhinolaryngologist and neurosurgeons to avoid injury of the vital structures during their procedures aiming to safe and complete eradication of the pathology.

## METHODS

Patients: This retrospective work was conducted on PNS multislice computed tomography (MSCT) for adult patients. The work was conducted in ORL and radiodiagnosis departments, Zagazig and Ain Shams University Hospitals, between January 2017 and January 2020. Patients undergone sinuses surgery before, neoplastic sinonasal lesions, sinonasal polyposis, significant cervical arthropathy, or head and/or neck injuries, and patients > 18 years old were excluded.

***Ethical consideration***

This study was conducted in follow to the Helsinki on Biomedical Research Involving Human Subjects declaration. The institutional review board (Zag- IRB) approved the methodology of the research. A prior written informative consent was gained from all enclosed subjects.

***Methods***

All MSCT scans were conducted with a 64 slices CT (GE lightSpeed VCT 64 slices). The 64 slice MDCT protocol was performed. Selecting of scanning in the coronal plan reduced the radiation dosage to patients. All patients were placed prone with hyper-extended head. The scanner gantry was angled perpendicular to hard palate. Adjoining slice CT methods were in use with 4mm sections wideness from anterior wall of the frontal sinuses to sphenoid sinuses. To have correct judgment of the adjacent structures and their relationships to the sphenoid sinuses, 2mm slices thickness was utilized beginning from anterior wall to posterior wall of the sphenoid sinuses. For proper visual images of the complex structure of such area, scanning was centered to the nasal cavity and paranasal sinuses. The state of the next variables was analyzed: pneumatization of ACP, PP, and GWS, protrusion of ON, ICA, MN, and vidian nerve (VN), and dehiscence of the walls of ON, ICA, MN, and VN.

Multi-planar reconstructions with subtle details in sagittal and axial plane were got for all subjects at a ordained post processing workstation. Films were examined in standardized manner to insure not missing any fine detail.

Dehiscence was defined as lack of seen bony density isolated the sinus from the examined anatomical structure along its course. When a clear-cut judgment between “total dehiscence” and “very thin bony wall” could not seen, the outcome were reported as a dehiscence. Projection (protrusion) of ICA and ON was detected via determination of any level of such structure protrusion into the spenoid sinus cavity. The existence of air density around such structures was used as a indication for the protrusion of MN and VN, at least in a coronal section. PP pneumatization was registered if it exceeds a horizontal plane traversing the vidian canal, while, we reported GWS pneumatization when it exceeds a vertical plane passing through the maxillary canal (figure 1).

## STATISTICAL ANALYSIS

Statistics was performed via the SPSS statistical software package (version 18; SPSS, Inc., Chicago, IL, USA). Significance was set at $P<0.05$.

## RESULTS

A hundred adult individuals (200 sphenoid sinuses), were enclosed in the current study with a 34.2 years mean age (range of age from 19 to 56 years). Pneumatization of PP, ACP and GWS were seen in 30 patients (30%), 16 patients (16%) and 21 patients (21%) of patients respectively (figure 2). Protrusion of ICA, ON, MN and VN were observed in 40 patients (40%), 36 patients (36%), 25 patients (25%) and 28 patients (28%) respectively (figure 3). Dehiscence of the bony wall of the ICA, the bony wall of the ON, the bony wall of the MN and the bony wall of the VN was encountered in 30 patients (30%), 31 patients (31%), 14 patients (14%) and 37 patients (37%) respectively (figure 1, 4).

There were high significant associations between PP pneumatization and ICA protrusion and between PP pneumatization and VN protrusion (p< 0.001) (table 1). There were high significant associations between ACP pneumatization and ICA protrusion and between ON protrusion and ACP pneumatization (p<0.001) (table2). There was a high significant association between GWS pneumatization and MN protrusion (p < 0.001) (table 3)

**Table 1:** The relation between pneumatization (PP) and protrusion

| | PP | |
|---|---|---|
| | **No** | **%** |
| **ICA (n = 40)** | 14 | 35 |
| **ON (n = 36)** | 2 | 5.6 |
| **MN (n = 25)** | 2 | 8 |
| **VN (n = 28)** | 12 | 42.8 |

P < 0.001

**Table 2:** The relation between ACP and protrusion

| | ACP | |
|---|---|---|
| | **No** | **%** |
| **ICA (n = 40)** | 8 | 20 |
| **ON (n = 36)** | 7 | 19.4 |
| **MN (n = 25)** | 1 | 4 |
| **VN (n = 28)** | 0 | 0 |

P < 0.001

**Table 3:** The relation between GWS and protrusion

| | GWS | |
|---|---|---|
| | **No** | **%** |
| **ICA (n = 40)** | 3 | 7.5 |
| **ON (n = 36)** | 3 | 7.5 |
| **MN (n = 25)** | 13 | 8.3 |
| **VN (n = 28)** | 2 | 7.1 |

P < 0.001

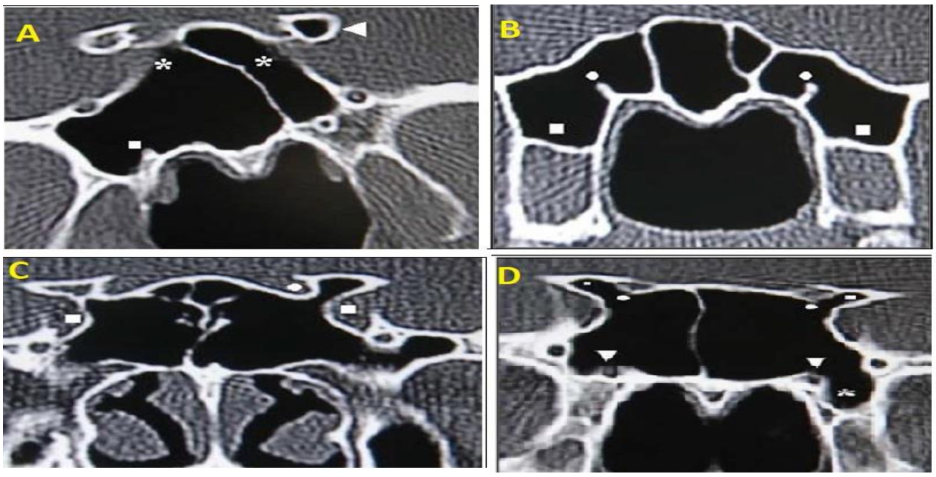


**Figure 1:** coronal CT shows; **A:** dehiscence of internal carotid arteries (*asterisks*), left anterior clinoid process pneumatization (*arrowhead*), and protrusion and dehiscence of right **v**idian canal (*square*). **B**: pneumatization of pterygoid processes (*squares*), and protrusion of vidian canals (*circles*). **C**: protrusion of left optic nerve (*circle*) and internal carotid arteries (*squares*). **D**: anterior clinoid processes pneumatization (*squares*), left pterygoid process pneumatization (*asterisk*), protrusion and dehiscence of optic nerves (*circles*), protrusion and dehiscence of vidian nerves (*arrowheads*).

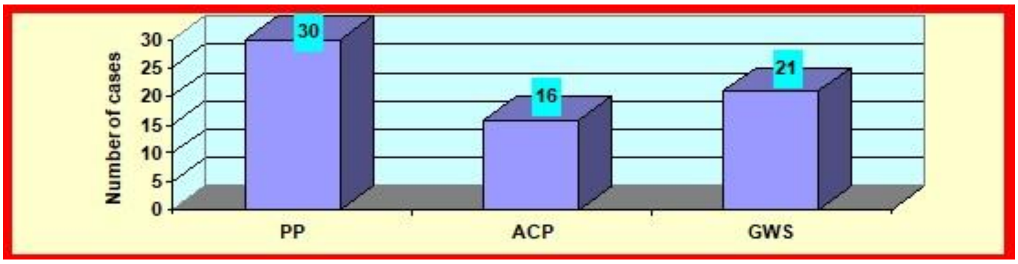


**Figure 2:** Pneumatization of ptergoid plate (PP), anterior clinoid process (ACP) and greater wing of sphenoid (GWS).

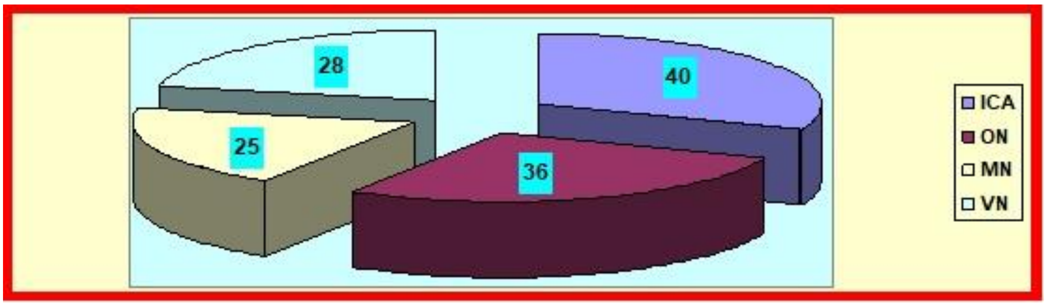


**Figure 3:** Protrusion of internal carotid artery (ICA), optic nerve (ON), Maxillary nerve (MN), and vidien nerve (VN).

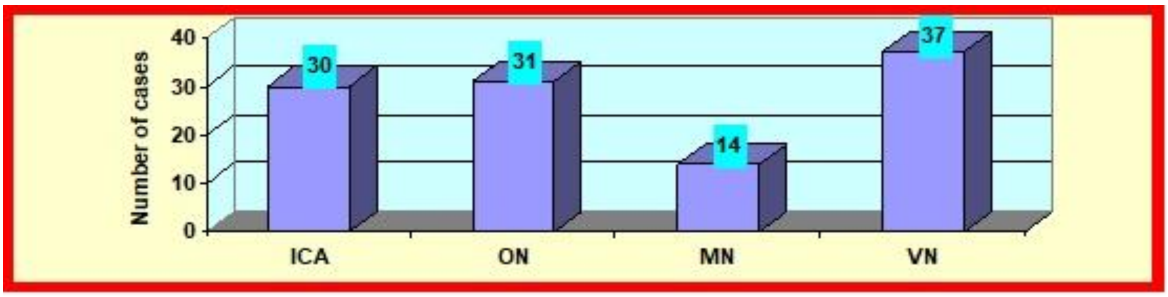

**Figure 4:** Dehiscence of bony wall of internal carotid artery (ICA), bony wall of optic nerve (ON), bondy wall of maxillary nerve (MN) and the bony wall of the vidien nerve (VN).

## DISCUSSION

Endoscopic sinus surgery (ESS) has gained the popularity as the main approach to the paranasal sinus. Frequent and wide ESS applications in parallel with increasing experience make it imperative to know in details the anatomy and the existent pathology before the procedure [13]. The variability of the deeply seated and challenging sphenoid sinus is great and common. Injury to the ICA or ON is a serious complication of the sphenoid sinus and the transsphenoidal surgeries [14]. The CT information of the sphenoid sinus should be well comprehended by the radiologists and the rhinosurgeons as a pre-request for harmless and efficient surgeries [10].

Depending on the magnitude of sphenoid sinuses pneumatization, the bony cover of the ICA, ON, vidian nerves and maxillary nerves, could be thin or even not present, exposing these structures to iatrogenic injury during ESS [15]. CT is the most precise imaging technique for examination of the paranasal sinuses with advantages of excellent appearance of the bony details (via the wide window set) and good soft tissue outline (via the narrow window set). Axial, coronal and sagital views may be helpful to delineate the sinonasal landmarks, but coronal CT scans gives most of the needed information for ESS [16].

Because of the complex anatomy and essential operative relationships of the sphenoid sinuses, the aims of the present study were to study the important structures in the sphenoid sinus and find anatomical variations in this area to guide otorhinolaryngologists and neurosurgeons to avoid injury of the vital structures during their sphenoid sinus procedures and the surrounding structures aiming at safe and complete eradication of the pathology. This study comprised CT PNS of 100 subjects.

PP pneumatization is recognized if it extends beyond a horizontal plane passing through the VC. We found pneumatization of PP in 30% of patients while **Turkdogan et al** [12] observed it in 36.75%. We found pneumatization of ACP in 16% of patients while **Turkdogan et al** [12] observed it in 21.25%.

Radiological experience uncovers that cautious identification of the ON and an ICA course appears to underestimate the incidence of protrusion. Thus, as a concept, ipsilateral ACP pneumatization is a key guide for the ON and ICA protrusion and so more suggestibility to hurt during ESS and so needs more care or even work under navigator. We found pneumatization of GWS in 30% of patients while **Hewaidi and Omami** [17] encountered it 20%.

We found ICA protrusion in 40% of patients and ICA dehiscence of it in 30% of patients. **Mamatha et al.** [10] evaluated the presence of the anatomical variations of the sphenoid sinuses that in relation to the transsphenoid sella surgeries and found ICA produced a clear prominence in the superolateral sinus wall in 50% and its bony dehiscence in 45%. **Turkdogan et al.** [6] observed ICA protrusion in a total of 51 sides.

We found protrusion of ON in 36% of patients and dehiscence of it in 31% of patients while **Hewaidi and Omami** [17] found it in 35.7%. Dehiscence of the ON bony wall was observed in 92 patients (30.7%). We found protrusion of MN in 25% of patients and dehiscence of it in 14% of patients while **Hewaidi and Omami** [17] encountered it in 24.3%. Dehiscence of the MN bony wall was seen in 39 (13%) patients. We found protrusion of VN in 28% of patients and dehiscence of it in 37% of patients while **Turkdogan et al**. [12] observed it in 34.25%.

In our study, we reported high significant association between ICA protrusion and ACP pneumatization, ON protrusion and ACP pneumatization, VN protrusion and PP pneumatization, and MN protrusion and GWS pneumatization ($p<0.001$).

**Wiebracht and Zimmer** [18] characterized the septation pattern of the sphenoid sinuses in a HRCT database. Pneumatization was described depending on the antecedently reported studies. The utilization of thin cuts images can guide radiographs in subjects without sphenoid rhinosinusitis and cranial base pathology and also allows for a complete evaluation of sphenoid sinuses anatomy without pathological distortions. The data showed large variability of sphenoid sinuses anatomy suggesting detailed pre0operative assessment use the endonasal trans-sphenoidal corridor to approach the skull base. **Turkdogan et al.** [12] concluded that the importance of CT for detecting the different sphenoid sinuses variations before ESS and anticipating complication during surgical procedures has been stressed again. As sphenoid sinuses pneumatization increased, the protrusion of adjacent vessels and nerves inside the sinus increase also.

Therefore, the complex anatomy and risky morphology of the sphenoid sinus tend to create a complexity of manifestations and possibility of significant complications. Incomplete knowing of the detailed anatomy doubtless increases the potentiality of grave or even fatal iatrogenic operative events. To limit such risks during procedures, an overcautious dissection should be coupled with a preoperative and intraoperative careful examination of the anatomic situations on CT scans. A detailed preoperative CT knowledge regarding the anatomical variants and pathological findings within the sphenoid sinuses could be highly beneficial during ESS. The clear understanding of the sphenoid sinuses morphology intensified the identification of the limits of dissection and so helps to lessen the complications possibility.

## CONCLUSIONS

Ratio of protrusion and dehiscence of the ICA and ON are frequent. The ICA and ON may not be well secured and thus could be injured during endoscopic sphenoid surgeries. ICA and/or ON protrusion is powerfully related to ipsilateral ACP pneumatization. Maxillary dehiscence and protrusion were less common. Vidian canal protrusion inside the sinus cavity was greatly associated with the PP pneumatization. Coronal CT screening is essential in the pre-surgical evaluation for sphenoid sinus surgeries to minimize vascular and neural and injuries.

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