Sphenoid Sinus Pneumatization, Septation, and the Internal Carotid Artery: A Computed Tomography Study

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Abstract

Background: The air spaces of the nasal cavity and the sphenoid sinus (SS) constitute a convenient corridor to access lesions of the skull base using the endoscopic endonasal transsphenoidal approach (EETA). Safe EETA depends on the SS and skull base anatomy of the patient. Individual variations exist in the degree and pattern of SS pneumatization. This study aims to examine the variations in SS pneumatization, the inter-sphenoid septum (ISS), and their relationship with the internal carotid artery (ICA) among adult Nigerians. **Materials and Methods:** We reviewed computerized tomography (CT) images of 320 adult patients that had imaging for various indications. This excluded those with traumatic, inflammatory, or neoplastic process that may alter anatomical landmarks. The images were evaluated for the types of SS pneumatization, number and insertion of ISS, and the protrusion of ICA into the sinus cavity. **Results:** Prevalence of SS pneumatization types: 1.9% conchal, 1.2% presellar, 56.6% sellar, and 40.2% postsellar. The lateral extension of SS occurred into the pterygoid in 138 patients (45.1%), greater wing 112 (35%), lesser wing 37 (11.6%), the full lateral type was seen in 97 (30.3%) patients. One ISS occurred in 150 (46.9%) patients, 162 (50.6%) had multiple, and 8 (2.5%) had none. ISS insertion into ICA bony covering occurred in 101 (31.6%) patients, whereas protrusion of ICA into SS cavity occurred in 110 (34.4%) patients. **Conclusion:** Variations of the SS, ISS, and ICA anatomy are present among native Africans. Detailed imaging evaluation of each patient is considered for EETA is mandatory.

Keywords: Internal carotid artery, intersphenoid septum, sphenoid sinus, variation

Introduction

The sphenoid sinus (SS) is a mucosal lined variably pneumatized posterior extension of the paranasal sinuses. It is located within the sphenoid bone in the middle cranial fossa.[1] Its relations are ethmoid air cells anteriorly, the cavernous sinus laterally, the pituitary fossa and planum sphenoidale superiorly, and the choana inferiorly. The sinus is divided into compartments by the midline intersphenoid septum (ISS) which may be absent, multiple, or incomplete. The ISS is frequently deviated laterally and may be attached to the bony covering of the adjacent optic nerve or internal carotid artery (ICA).[2] Extensive pneumatization of the SS may bring it into proximity to the nearby neurovascular structures such as the optic nerve, the ICA, and the ventral surface of the brain stem.[3]

The natural air spaces of the nasal cavity and the SS constitute a convenient corridor to access and treat lesions of the skull base during the endoscopic endonasal transsphenoidal approach (EETA). This relationship of the sphenoid cavity to the nasal cavity below and the pituitary gland above makes the transsphenoidal route the surgical approach of choice for sellar tumors.[4] The EETA has minimal invasiveness; lower incidence of complications with lower morbidity and mortality rates compared with traditional open approaches.[1,4] Extended approaches through the SS have made it possible to reach different parts of the skull base from the crista galli to the spinomedulary junction.[1] Anatomic variations in the nasal cavity and the SS make preoperative imaging evaluation not only useful for diagnosis but also valuable for surgical mapping to ensure safe access and improved surgical outcomes.[5]

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The anatomical variations within the nasal cavity that are relevant to safe endoscopic access to the skull base are septal deviation, spina septi, and concha bullosa. While anatomic variations of the SS that may impact safe endoscopic access include the degree and extensions of pneumatization, the thickness of the bony covering of the adjacent neurovascular structures and whether these structures protrude into the sinus cavity. The number and insertions of the intersphenoid septum and the presence of Onodi cells are also important considerations in planning safe surgical access.[5]

Both computed tomography (CT) and magnetic resonance imaging (MRI) are required for appropriate patient selection and for intraoperative surgical guidance in EETAs. MRI has a higher soft-tissue resolution but provides less information about bony structures which are conventionally used as anatomic landmarks to guide endoscopic surgery. For this reason, CT is preferred for detecting and delineating the bony landmarks and anatomic variants that facilitate safe access into the SS for the surgeon[1], whereas MRI provides further details about the location of the lesion and its relationship to the adjacent neurovascular structures.[5]

The variations of SS anatomy have been studied in different populations[6-8] including Nigerians.[9,10] However, neither of the Nigerian studies described the lateral extensions of SS pneumatization into the greater wing of sphenoid and the pterygoid process as described by Wang *et al*.[11] These lateral extensions facilitate access to the cavernous sinus, middle cranial fossa, and the petrous apex.[11] Moreover, the practice of EETA for skull base surgery is growing in Nigeria.[12] The aim of this study is to examine the anteroposterior and lateral extensions of SS pneumatization as well as the variations of the intersphenoid septum and the ICA in relation to the SS cavity in an adult Nigerian population.

Materials and Methods

This is a retrospective cross-sectional study of adult patients that had cranial CT for various indications in a tertiary medical facility in South Western Nigeria from June 2010 to May 2012. We studied the CT images, of the SS, of patients with no apparent feature or indication of sinus disease. Patients younger than 18 years, those with skull base fracture, prior skull cranial surgery, and inflammatory or neoplastic disease that may alter normal anatomical landmarks needed for SS identification and evaluation were excluded from the study.

Image acquisition was done using a 4-slice CT scanner (Brightspeed, GE Healthcare) in the axial plane with slice thickness of 2.5 mm and reconstructed at 1.25 mm. The images were analyzed by two consultant Radiologists (OCF and BOI) using a RadiAnt Dicom viewer version 4.2.1 (Medixant, Poland). Evaluation of the primary axial and reconstructed coronal and sagittal views was done using the bone window. The images were assessed for diagnostic image quality, and the variations of SS anatomy were identified according to the following criteria.

Sinus classification [2,3]

The SS can be classified based on pneumatization into conchal, presellar, sellar, and postsellar. In conchal type, the region below the sella is completely ossified and consists of a solid block of bone with no air cavity [Figure 1]. In the presellar type, the air cavity does not penetrate beyond a vertical plane parallel to the anterior sellar wall, [Figure 2]. In the sellar type, the sinus is well developed, and pneumatization extends beyond the tuberculum sella below the sella and sometimes with bulging of the sellar floor into the sinus cavity [Figure 3]. In the postsellar type, the air cavity extends into the body of the sphenoid, continues beyond the posterior margin

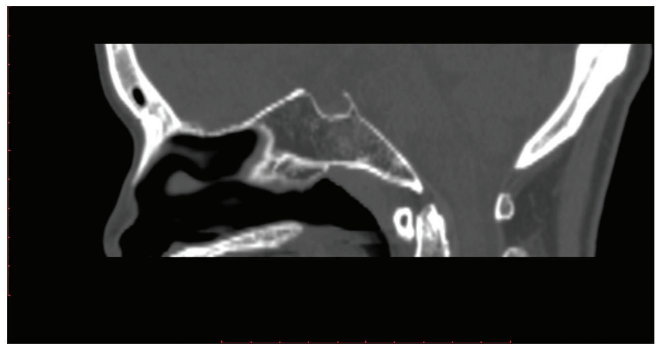

Figure 1: Sagittal computed tomography image. Conchal: The region below the sella consists of a solid block of bone with no air cavity

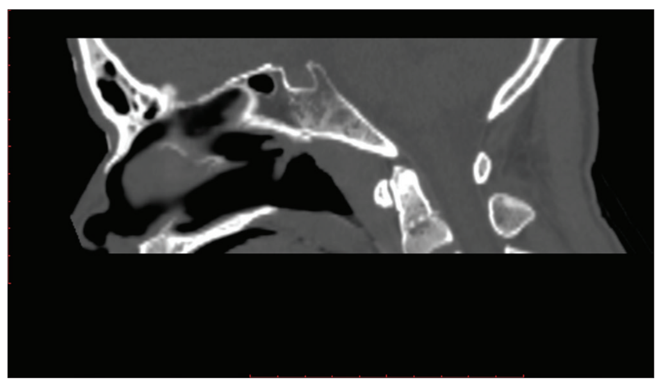

Figure 2: Sagittal computed tomography image. Presellar: The air cavity does not penetrate beyond a vertical plane parallel to the anterior sellar wall

Figure 3: Sagittal computed tomography image. Sellar: The sinus is well developed; pneumatization extends beyond the tuberculum sella below the sella

of the dorsum sella into the clivus bone. Pneumatization of the dorsum sella was noted when present [Figure 4].

Similarly, lateral sinus extensions are recognized based on whether the lateral wall of the SS extends laterally beyond a straight line crossing the medial edges of the vidian canal and the foramen rotundum, this line is called the VR line (VR = Vidian to Rotundum). In the greater wing type, the sinus extends laterally between the foramen rotundum and the vidian canal (beyond the VR line) into the greater wing. In the pterygoid type, the sinus extends laterally between the foramen rotundum and the vidian canal (beyond the VR line) and inferiorly into the pterygoid process. In the full lateral type, the sinus extends laterally into both the greater wing and the pterygoid process [Figure 5]. In the lesser wing type, the sinus extends through the optic strut into the anterior clinoid process (ACP) [Figure 5].

Presence and insertion of intra-sphenoid septa

The presence of ISS and their insertion into the midline, bony covering of the carotid or the lateral wall of the SS was evaluated on axial and coronal views [Figure 6]. Complete septum – An intersphenoid septum that extends from the anterior to the posterior wall of the SS on the axial view or superior to the inferior wall on the coronal view. Incomplete septum – a septum that does not extend from wall to wall as described for the complete septum.

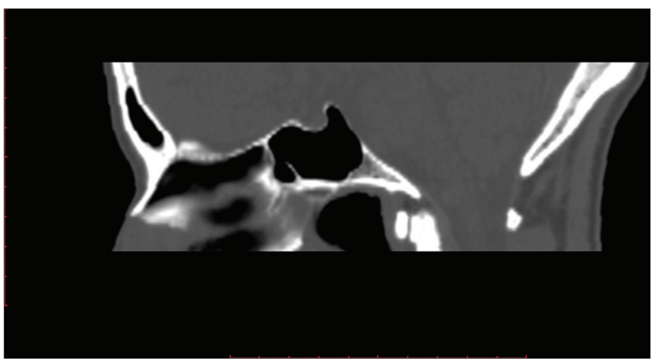

Figure 4: Sagittal computed tomography image. Post-sellar: The air cavity extends into the body of the sphenoid, continues beyond the posterior margin of the dorsum sella into the clivus bone. Pneumatization of the dorsum sella is also present

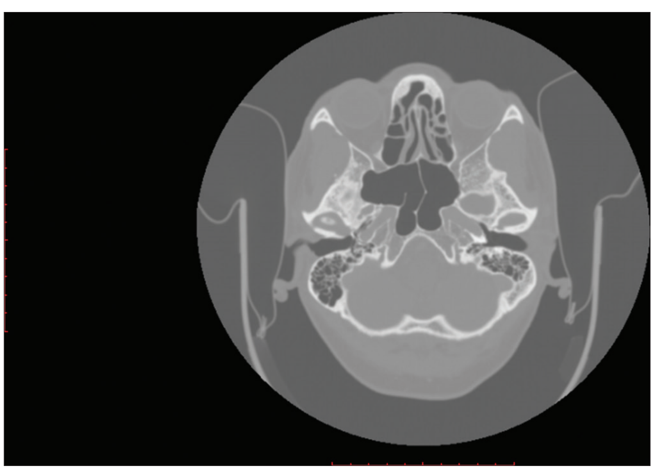

Figure 6: Axial computed tomography image. Complete intersphenoid septum inserted into the posterior wall of the sphenoid sinus, incomplete ISS inserted into the bony covering of the right internal carotid artery, bilateral internal carotid artery protrusion

Presence or absence of internal carotid artery protrusion

The presence or absence of ICA protrusion into the SS cavity was evaluated on the axial (for paraclival ICA) and coronal views (for parasellar ICA) [Figure 5]. Protrusion was defined as having the carotid artery surrounded by sinus air on any plane and deemed to be absent when the ICA is completely embedded in bone.

Onodi cell

The Onodi cell is identified on the coronal and sagittal views as an air cell above the SS that is seen to continue with a posterior ethmoid air cell [Figure 7a and b].

Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 20.0. (Armonk, NY: IBM Corp.) and results were presented using descriptive statistics.

Results

Three hundred and twenty patients comprising 209 males (65.3%) and 111 females (34.7%) were studied. The age range

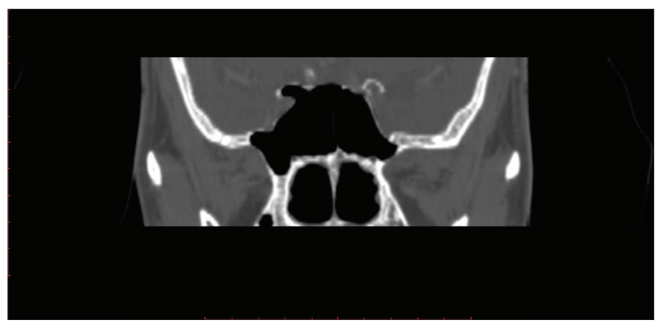

Figure 5: Coronal computed tomography image. Complete lateral type with extension of sphenoid sinus into greater wing of sphenoid (square), and pterygoid process (triangle) on the right. Ipsilateral extension of sphenoid sinus into the anterior clinoid process (circle) is also present

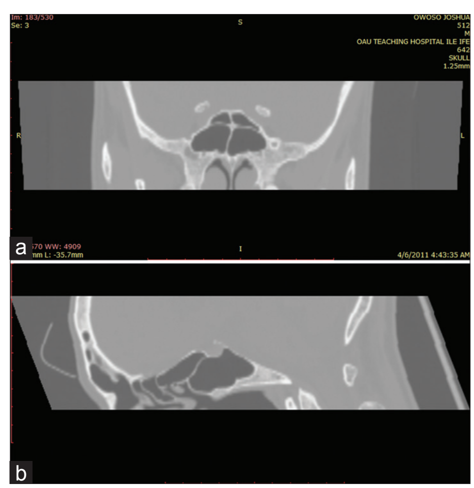

Figure 7: (a) Coronal computed tomography image. Bilateral Onodi cells (circles). (b) Sagittal computed tomography image. Onodi cell (circle)

is 18–92 (mean = 48.1, standard deviation = 19.6) years. Indications for cranial CT among the study population were trauma 134 (41.9%), stroke 114 (35.6%), space-occupying lesions 14 (4.4%), seizures 14 (4.4%), headache 10 (3.2%), and others (indications with frequency <10) 53 (16.6%) patients [Table 1].

The most common type of SS in this study was the sellar type, observed in 181 patients (56.6%). This was followed by the postsellar type seen in 129 patients (40.3%). The conchal and presellar types were observed in six patients (1.9%) and four patients (1.2%), respectively. One patient had aplasia involving the right SS, that is, aplasia of the right hemi sphenoid (0.3%). The sellar type of SS was seen in this patient [Figure 8]. Hemisphenoid aplasia was absent in 301 patients (99.7%).

Pneumatization of the dorsum sella was observed in five patients (1.6%), whereas the dorsum sella was not pneumatized in 315 patients (98.4%).

The types of lateral extensions of the SS observed among our study group were the pterygoid type seen in 138 patients (45.1%), greater wing type, 112 patients (35%) and the lesser wing type 37 patients (11.6%). The full lateral type was observed in 97 patients (30.3%). Lateral extensions of sphenoid pneumatization were present only in the sellar and postsellar types of SS. One hundred and thirty patients (40.6%) had no lateral extension of their SS [Table 2].

Table 1: Subject's demographics and gender distribution of sphenoid sinus pneumatization types

Variable	Female (*n*=111)	Male (*n*=209)	Total
Mean age (years)	51.12	46.38	
Indications for CT			
Trauma	19	95	114
Stroke	42	53	95
Space occupying lesion	17	16	33
Seizures	7	7	14
Headache	6	4	19
Others	20	34	54
SS type			
Conchal	5	1	6
Presellar	2	2	04
Sellar	117	64	181
Postsellar	85	44	129
Dorsum sella pneumatization	1	3	04
Lateral extension of SS			
Lesser wing type	23	14	37
Greater wing	67	45	112
Pterygoid process	81	57	138
Full lateral	58	39	97
Onodi cells	23	36	59
ISS insertion into ICA bony covering	65	56	101
ICA protrusion into SS	74	36	110

CT – Computerized tomography; ICA – Internal carotid artery; ISS – Inter-sphenoid septum; SS – Sphenoid sinus

Onodi cells were observed in 59 patients (18.4%), whereas the rest had none.

A single intersphenoid septum was seen in 150 patients (46.9%), 162 patients (50.6%) had multiple septa, whereas 8 (2.5%) patients had no septum within their SS. One hundred and fifty-four patients (48.1%) had at least one incomplete septum. One hundred and fifty-nine patients (49.7%) had at least one septum inserted into the midline, whereas 74 patients (23.1%) and 87 patients (27.2%) had at least one septum inserted into the right and left lateral walls of the sphenoid septum, respectively.

Intersphenoid sinus septae (ISS) insertion into the bony covering of ICA was observed on the right in 38 patients (11.9%), on the left in 41 patients (12.8%) and bilaterally in 22 patients (6.9%). Fifty-nine (18.4%) of the septae inserted into the bony covering of the carotid artery were incomplete.

Protrusion of the paraclival ICA into the SS cavity was present on the right in 21 patients (6.6%), on the left in 13 patients (4.1%) and bilaterally in 50 patients (15.6%): while in the parasellar carotid artery, protrusion into the SS cavity was seen on the right in 19 patients (5.9%), on the left in 15 patients (4.7%) and bilaterally in 15 patients (4.7%). Twenty-three patients (7.2%) had both paraclival and parasellar ICA protrusion, whereas in 210 patients (65.6%), the ICA was completely embedded in bone.

The age group and gender of the patients had no significant relationship with either the SS type or the presence of lateral extension of SS pneumatization.

Both the sellar and postsellar types of SS have strongly significant associations with the presence of ISS insertion into the ICA (P = 0.0001), ICA protrusion into the SS cavity (P = 0.0001) and lateral extensions of SS (P = 0001). A strongly significant association was also observed between the paraclival and parasellar ICA protrusion into the SS cavity (P = 0.0001).

Discussion

The most common variant of SS in this study is the sellar type while the lateral extension of the SS pneumatization occurred

Figure 8: Coronal computed tomography image. Right hemi-sphenoid sinus aplasia: appearing as a solid block of bone (circle). The left hemi-sphenoid sinus is pneumatized

Table 2: Sphenoid sinus types and the frequency of inter-sphenoid septum insertion into the bony covering of the internal carotid artery, internal carotid artery protrusion into sphenoid sinus and the types of lateral extension of sphenoid sinus

SS type	ISS insertion into bony covering of ICA	ICA protussion into SS	Lesser Wing type	Greater Wing type	Pterygoid type	Full lateral type
Conchae	0	0	0	0	0	0
Presellar	0	0	0	0	0	0
Sellar	30	32	05	37	60	31
Postsellar	71	78	32	75	78	66
Total	101	110	37	112	138	97

ISS – Intersphenoid septum; ICA – Internal carotid artery; SS – Sphenoid sinus

most commonly into the pterygoid process. Insertion of the intersphenoid septum (ISS) into the bony covering of the ICA and the protrusion of the ICA into the SS cavity occurred in 31.6% and 34.4% of patients, respectively.

The prevalence of the different types of SS pneumatization, relative to each other, in this study is similar to what obtains in the literature. That is, the conchal and the presellar types have low prevalence when compared to the sellar and postsellar types with the sellar usually being the most common.[1,4,7,13] Nevertheless, a wide variation exists in the actual prevalence of each variant. The variations range from 2% to 28% conchal, 17%–21% presellar, 54%–85% sellar, and 22%–43.3% postsellar.[14] The wide range may be attributed to the fact that some studies were on cadavers,[15] whereas others were imaging studies[16] with consequent lack of uniformity in the definition of the variants.[14] The prevalence of 1.9% conchal, 1.2% presellar, 56.6% sellar, and 40.2% postsellar in this study is different from that of a previous imaging study among Nigerians, by Idowu *et al*.,[9] that found 0% conchal, 5% presellar, 88.3% sellar, and 6.7% postsellar. The difference is probably due to the smaller sample size (60 patients) in the aforementioned study. However, the combined prevalence of the sellar and postsellar types of SS (96.8% and 95%) in ours and the Idowu *et al*. study are similar. Although, findings from these two Nigerian studies are within the range found by other authors. While our prevalence of the presellar type is low as compared to that of Tomovic *et al*.[14] and Lu *et al*.,[6] it is similar to that of Wang *et al*.[11] Tomovic *et al*. in their study of a multiethnic population comprising African Americans, Caucasians, Asians, and Hispanics did not find any difference in regard to ethnicity. In contrast, Lu *et al*.[6] in a study among the Chinese showed that the conchal and presellar types are more prevalent in Chinese individuals. Therefore, some degree of ethnoracial differences in the prevalence of individual SS types cannot be ruled out considering that we studied a native African population.

Among the different types of SS pneumatization, the sellar and the postsellar, with a combined prevalence of 96.9% in this study, are the most favorable for the EETA to pituitary surgery. This is because the anterior wall of the sella and the sellar floor typically measure <1 mm in thickness in these variants, thereby facilitating easy access to the sellar floor.[11] In the postsellar type, there is extension of the SS into the clivus to varying degrees, sometimes almost to the posterior margin. In such cases, lesions located in the posterior cranial fossa are potentially accessible using the EETA. This includes lesions along the midline, from the dorsum to the anterior lip of the foramen magnum and odontoid process.[1,11] However, the clivus could be vulnerably thin, giving rise to a risk of perforation and an unplanned entry into the posterior cranial fossa during EETA. This may lead to complications such as injury to neurovascular structures and cerebrospinal fluid leakage.[15] The conchal type of SS precluded the EETA in the past because of the thickness of the bone in the anterior wall of the SS. Improvements in surgical instrumentation such as the high-speed diamond drill and neuronavigation[1] have made transphenoidal endoscopic surgery possible in all SS types. Nevertheless, the conchal and presellar types require bone drilling to reach the sellar floor. We expect that patients with aplasia involving one of the sinuses, as observed in one of our subjects, will require even more drilling. However, there may be a concomitant risk of injury to nearby neurovascular structures during bone drilling.[11,14]

The lateral extensions of the SS identified in the study population, using Wang's[11] classification, are greater wing (35%), pterygoid (45.1%), and the full lateral type (30.1%), whereas 40.6% of the patients had no lateral extension of their SS. The finding that the pterygoid type of lateral extension is the most common in our study is similar to what obtains among Indians.[17] Separate studies by Wang *et al*. and Lu *et al*. found the full lateral type to be most prevalent in 41.6% and 77.1% of their study populations, respectively. However then, these two studies[6,11] showed differences in the prevalence of the individual variants. The combined prevalence of lateral extensions of SS in our study of 59.5% is also similar to that by Hiremath *et al*. in the Indian population (58.8%).[17] These disparities in the prevalence of individual variants may further strengthen the argument for ethnoracial differences in the SS anatomy.

Pneumatization of the ACP was seen in 11.6% of our study population, whereas another study of Nigerian patients by Fasunla *et al*.[10] found a prevalence of 14.5%. This may be due to the fact Fasunla *et al*. worked with a 64 slice CT scanner which has a higher resolution than the 4 slice scanner used in our study, hence, the higher prevalence of ACP pneumatization among their individuals. The values from both studies are, however, within the range of 5%–24.1% recorded in the literature.[1,17]

The lateral extensions of SS project below the floor of the middle cranial fossa where they are adjacent to the (anteromedial and anterolateral) middle fossa triangles. Therefore, they facilitate transsphenoidal and transmaxillary endoscopic access to the anteromedial part of the cavernous sinus, middle fossa, and the Meckel's cave.[5,11] The corollary of these extensions is the protrusion of nearby neurovascular structures (ICA, the optic, vidian, and maxillary nerves) into the sinus cavity thereby making meticulous surgical techniques imperative to prevent injury to these vital structures during the transphenoidal approach.

The Onodi cell is the most posterior ethmoidal cell. It develops superolaterally to the SS and pushes the SS downward. It was seen in 18.4% of the study population, but a range of 8%–33.3% has been reported in the literature.[18] The Onodi cell is directly related to the optic nerve and the ICA. Hence, caution must be exercised in patients with this variant. The SS and the Onodi cell share a wall; the posterior wall of the Onodi cell is the anterior wall of the SS. During EETA, the cell interferes with exposure of the sellar floor.[18] Furthermore, the Onodi cell can easily be mistaken for the SS causing the surgeon to enter the Onodi cell rather than the SS. This could lead to an unintentional entry into the middle cranial fossa with the possibility of injury to the optic nerve and ICA.[1,18]

The inter-sphenoid septum (ISS) is an important anatomical landmark within the SS; it varies in number and point(s) of insertion on the sinus wall but often inserting on the bony covering of the ICA. Previously reported the prevalence of ISS insertion into ICA bony covering ranges from 4.9% to 89%[15,19,20] and in our study, the prevalence is 31.6%. During endoscopic surgery, the septum must be removed to expose the sella floor, thereby creating adequate surgical corridor.[20] Therefore, extreme caution is required while removing the septum in patients with ISS insertion into the bony covering of ICA, because an avulsion fracture of the septum may rupture the vessel causing an intraoperative emergency.

In this study, protrusion of the ICA into the SS cavity was present in 34.4% of subjects. This is higher than what was observed by Fasunla *et al*.[10] who also studied Nigerians and found a prevalence of 27.3%. The discrepancy in the prevalence between the two studies could be because Fasunla *et al*. defined ICA protrusion as the presence of more than half the circumference of the ICA in the SS cavity while we defined it as having the ICA surrounded by air on any plane. Like Dal Secchi *et al*.,[3] we explored the association between the protrusion of parasellar and the paraclival ICA into the SS cavity, and we also found a statistically significant relationship (P = 0.0001). Similar to the other anatomical variations of the SS, the reported range of the prevalence of ICA protrusion into SS is wide. This is from 7% among Indians[17] to 41% among Libyans,[21] and remarkably, 50% in another study of Indian patients.[22] The multiethnic study by Tomovic *et al*.[14] found a prevalence of 28%. This further supports the notion of ethnic variations in SS types.

The limitations of this study include its retrospective nature. Furthermore, we used a 4 slice CT scanner rather than a 64 slice scanner which has higher image resolution and nearly isotropic multiplanar reconstructions. Moreover, there was no endoscopic correlation of our findings. Nevertheless, to the best of our knowledge, this is perhaps the largest series about the SS among Nigerians to date. We are of the opinion that this study has provided initial information about the anatomical variations of the SS anatomy (especially the lateral extensions of the sinus) in our locality.

Conclusion

Variations of the anteroposterior and lateral extensions of SS pneumatization are common among our study participants. The study also shows that the inter-sphenoid septum and the ICA protrusion demonstrate remarkable variations in relation to the SS cavity. We, therefore, recommend mandatory detailed preoperative imaging evaluation of each patient being considered for endoscopic transsphenoidal approach to the skull base.

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Conflicts of interest

There are no conflicts of interest.

References

1. García-Garrigós E, Arenas-Jiménez JJ, Monjas-Cánovas I, Abarca-Olivas J, Cortés-Vela JJ, De La Hoz-Rosa J, *et al.* Transsphenoidal approach in endoscopic endonasal surgery for skull base lesions: What radiologists and surgeons need to know. Radiographics 2015;35:1170-85.
2. Budu V, Mogoantă CA, Fănuţă B, Bulescu I. The anatomical relations of the sphenoid sinus and their implications in sphenoid endoscopic surgery. Rom J Morphol Embryol 2013;54:13-6.
3. Dal Secchi MM, Dolci RL, Teixeira R, Lazarini PR. An analysis of anatomic variations of the sphenoid sinus and its relationship to the internal carotid artery. Int Arch Otorhinolaryngol 2018;22:161-6.
4. Zador Z, Gnanalingham K. Endoscopic transnasal approach to the pituitary – Operative technique and nuances. Br J Neurosurg 2013;27:718-26.
5. Learned KO, Lee JY, Adappa ND, Palmer JN, Newman JG, Mohan S, *et al*. Radiologic evaluation for endoscopic endonasal skull base surgery candidates. Neurographics 2015;5:41-55.
6. Lu Y, Pan J, Qi S, Shi J, Zhang X, Wu K. Pneumatization of the sphenoid sinus in Chinese: The differences from Caucasian and its application in the extended transsphenoidal approach. J Anat 2011;219:132-42.
7. Wiebracht ND, Zimmer LA. Complex anatomy of the sphenoid sinus: A radiographic study and literature review. J Neurol Surg B Skull Base 2014;75:378-82.
8. Elkammash TH, Enaba MM, Awadalla AM. Variability in sphenoid sinus pneumatization and its impact upon reduction of complications following sellar region surgeries. Egypt J Radiol Nucl Med 2014;45:705-14.
9. Idowu OE, Balogun BO, Okoli CA. Dimensions, septation, and pattern of pneumatization of the sphenoidal sinus. Folia Morphol (Warsz) 2009;68:228-32.
10. Fasunla AJ, Ameye SA, Adebola OS, Ogbole G, Adeleye AO,

Adekanmi AJ. Anatomical variations of the sphenoid sinus and nearby neurovascular structures seen on computed tomography of black Africans. East Cent Afr J Surg 2012;17:57-64.
11. Wang J, Bidari S, Inoue K, Yang H, Rhoton A Jr. Extensions of the sphenoid sinus: A new classification. Neurosurgery 2010;66:797-816.
12. Kanu OO, Bankole OB, Ojo OA, Olatosi JO, Dawang DY, Yusuf AS, *et al*. Experience of Transnasal Pituitary Surgery in Nigeria, Sub-Saharan Africa; AANS, E-Posters; 2018. Available from: http://www.aans.org/Online. [Last accessed on 2018 Jul 07].
13. O'Brien WT Sr., Hamelin S, Weitzel EK. The preoperative sinus CT: Avoiding a "CLOSE" call with surgical complications. Radiology 2016;281:10-21.
14. Tomovic S, Esmaeili A, Chan NJ, Shukla PA, Choudhry OJ, Liu JK, *et al.* High-resolution computed tomography analysis of variations of the sphenoid sinus. J Neurol Surg B Skull Base 2013;74:82-90.
15. Banna M, Olutola PS. Patterns of pneumatization and septation of the sphenoidal sinus. J Can Assoc Radiol 1983;34:291-3.
16. Hamid O, El Fiky L, Hassan O, Kotb A, El Fiky S. Anatomic variations of the sphenoid sinus and their impact on trans-sphenoid pituitary surgery. Skull Base 2008;18:9-15.
17. Hiremath R, Suligavis, Pol M, Anegundi T, Rudrappa K. A computed tomographic study on the anatomic variations of the sphenoid sinus and its related structures in a North Karnataka population. J Clin Diagn Res 2012;6:1262-5.
18. Shin JH, Kim SW, Hong YK, Jeun SS, Kang SG, Kim SW, *et al.* The onodi cell: An obstacle to sellar lesions with a transsphenoidal approach. Otolaryngol Head Neck Surg 2011;145:1040-2.
19. Ramalho CO, Marenco HA, de Assis Vaz Guimarães Filho F, da Costa MD, de Oliveira Santos BF, de Paula Santos R, *et al.* Intrasphenoid septations inserted into the internal carotid arteries: A frequent and risky relationship in transsphenoidal surgeries. Braz J Otorhinolaryngol 2017;83:162-7.
20. Fernandez-Miranda JC, Prevedello DM, Madhok R, Morera V, Barges-Coll J, Reineman K, *et al.* Sphenoid septations and their relationship with internal carotid arteries: Anatomical and radiological study. Laryngoscope 2009;119:1893-6.
21. Hewaidi G, Omami G. Anatomic variation of sphenoid sinus and related structures in Libyan population: CT scan study. Libyan J Med 2008;3:128-33.
22. Mamatha HS, Prasanna LC, Saraswathi G. Variations of sphenoid sinus and their impact on related neurovascular structures. Curr Neurobiol 2010;1:121-4.