

Anatomical Variations of the Sphenoid Sinus and Nearby Neurovascular Structures Seen on Computed Tomography of Black Africans.

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Background: To describe the relationship of optic nerves and internal carotid arteries to sphenoid sinus using Computerized Tomography (CT) in a black African population.

Methods: We retrospectively reviewed both the coronal and axial CT images of the paranasal sinuses and brain of 110 patients which were obtained for head and neck diseases other than malignancies, nasal polyps and craniofacial trauma using computer workstation with Clearcanvas software. All scans were evaluated on both soft tissue and bone windows for the identification of protrusion of optic nerve (ON) and internal carotid artery (ICA) into the sphenoid sinus, pneumatization of the anterior clinoid process (ACP) and position of the sphenoid septum.

Results: Forty two (38.2%) cases have ON protruding into the sphenoidal sinus and ON wall dehiscence occurred in 15(13.6%). Protrusion of the ICA into the sphenoid sinus was on CT images of 30 (27.3%) patients and dehiscence of bony sphenoidal wall of ICA occurred in 12 (10.9%) patients. The anterior clinoid process (ACP) was pneumatized in 16 (14.5%) cases and sphenoidal septum was absent in 3(2.7%) cases.

Conclusions: Anatomic variations in relationship of sphenoid sinus to ON and ICA are seen on CT examinations in black Africans population. The endoscopic head and neck surgeons managing black Africans should be aware of these varied relationships and ensure a detailed pre-operative review of the CT scans to avoid the potential risks of blindness, uncontrollable haemorrhage and death that may attend anatomically uninformed sphenoidal surgeries.

Introduction

The sphenoid sinus is an aerated mucosa-lined cavity occupying a central location at the skull base. It is present at birth but its developmental pneumatization continues until adulthood when it reaches the maximum size¹. Its clinical importance apart from being a paranasal sinus also borders on its intimate relationship with vital neurovascular and endocrine structures such as the optic nerve (ON), internal carotid artery (ICA), cavernous sinus and pituitary gland².

The pneumatization pattern of the sphenoid sinus is variable and can extend to surround the anterior clinoid process (ACP), foramen rotundum, vidian canal, pterygoid process, or the maxilloethmoid process³. The optic nerve passes usually in a superolateral relation to the sphenoid sinus but occasionally it may pass through the sinus⁴⁻⁸. This varied relationship of the optic nerve to the sphenoid sinus, which may include that of internal carotid artery, is due to the inconsistent nature of the sphenoid sinus pneumatization. The sphenothmoidal (onodi) cells which are the most posterior cells of the posterior ethmoidal sinus sometimes develop and extend into the superolateral wall of the sphenoid sinus where they may surround the optic nerve. These situations tend to occur when there is excessive pneumatization of the basi-sphenoid⁹. These related vital structures like ON and ICA may occasionally be covered by a thin bony layer or mucosa in the sphenoid sinus. These situations render them vulnerable to injury during endoscopic intranasal

ethmoidectomy or sphenoidectomy and such injuries, though uncommon, are well documented possible complications of transphenoidal surgical procedures¹⁰.

A detailed knowledge of the anatomy of sphenoid sinus and its related adjacent structures preoperatively is thus crucial to the prevention of unintentional damage to these vital structures which can result in blindness or uncontrollable bleeding during primary endoscopic intranasal sphenoidal- or endoscopic endonasal transphenoidal skull base surgery¹¹.

Although the role of ethnicity on variations in sinonasal anatomy has been documented¹² few published reports exist globally on this subject. Literature from indigenous black African population is even much rarer¹³. Therefore, the aim of this study is to describe the varied locations of the ON and ICA in relation to the sphenoid sinus using computerized tomographic scan in a black African population. The pneumatization pattern of the anterior clinoid process and the position of sphenoid septum in relation to the midline would also be described.

Patients and Methods

We retrospectively reviewed paranasal sinuses and brain computerized tomographic (CT) scans of 110 patients which were obtained for disease conditions of the head and neck region other than malignancies, nasal polyps and craniofacial, paranasal sinus or base of skull trauma at the Departments of Otorhinolaryngology and Radiology of the University College Hospital, Ibadan, Nigeria. Both coronal and axial images of the paranasal sinuses and brain of the patients were obtained with 3.0-mm section thickness, at 120 kV and 300 mA on Aquilion 64- CT Scanner (ToshibaTM). Images were then transferred into a computer workstation with Clearcanvas software version 2.0TM (Clearcanvas Inc. Toronto, Canada) for evaluation of the sphenoid sinuses. All scans were evaluated using bone window (window width 2,000 Hounsfield units [HU]; window level 500 HU) and soft tissue window (window width 200 HU; window level 40 HU) for the identification of the protrusion of the ON and ICA into the sphenoid sinus, pneumatization of the anterior clinoid process and position of the sphenoid septum. The coronal CT scan was used for the identification of ON protrusion into the sphenoid sinus, while axial cuts better delineated the course of the ON and ICA to the sphenoid sinus. The CT scan images were first assessed by the principal investigator (AJF) and thereafter, independently by four other co-authors (GO, AJA, OSA, SAA) according to modification of Delano system of classification by Batra et al⁸.

The relationship of ON to the sphenoid sinus was assessed as follows;

- Type 0: Does not border sphenoid sinus
- Type 1: Adjacent to sphenoid sinus
- Type 2: Indentation on sphenoid sinus
- Type 3: Less than 50% exposure of optic nerve in sphenoid sinus
- Type 4: Optic nerve traversing sphenoid sinus

The relationship of ICA to the sphenoid sinus was classified as either protrusion into the sphenoid sinus or presence of bone dehiscence. Protrusion of the ICA into the sphenoid sinus was defined as the presence of more than half the circumference of the ICA into the sphenoid sinus cavity with or without defects in their bony margins. Bone dehiscence was defined as the absence of visible bone density separating the sinus from the course of the ICA. Statistical analysis was performed using the statistical package for social sciences (SPSS Inc, Chicago, IL) for Windows. The Results were expressed as mean \pm standard deviation. A p-value < 0.05 was considered statistically significant.

Results

There were 59 (53.6%) males and 51 (46.4%) females with M: F ratio of 6: 5. Their ages ranged from 18 to 88 years with a mean age of 48.38 years \pm 18.16.

The relationship of ON to sphenoid sinus is as shown in Table 1. Forty two (38.2%) cases have ON protruding into the sphenoidal sinus [Types 2 - 4] while 21 (19.1%) cases showed a probabilistic vulnerability of ON to injury during endoscopic sphenoidectomy or trans-sphenoidal pituitary surgery in that the ON was found to be either partially or totally [Types 3 - 4] exposed within the sphenoid sinus. Some examples of the CT images demonstrating the different types of ON relationship to the sphenoid sinus are shown in figures 1a – e. No bone dehiscence was noticed in Type 0, Type 1 and Type 2 pneumatisation patterns of the sphenoid sinus. However, dehiscence occurred in 15(13.6%) patients: right sided in 7 (6.4%) cases, left side in 6 (5.5%) cases and bilateral involvement in 2 (1.8%) cases. Six (40%) of the cases were Type 4.

Table 1. Relationship of Optic Nerve to Sphenoid Sinus

Types	Right side	Left side	Bilateral	Total	Percentage
0	0	1	32	33	30.0
1	6	5	24	35	31.8
2	8	12	1	21	19.1
3	5	8	2	15	13.6
4	3	3	0	6	5.5
Total	22	29	59	110	100.0

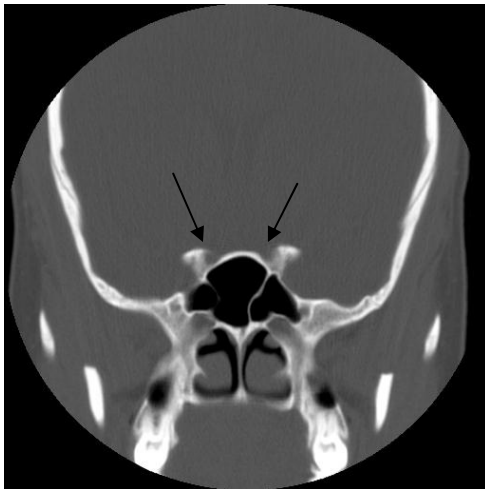


Figure 1a. Bilateral Type 0 ON (Optic nerves do not border sphenoid sinus)



Figure 1b. Unilateral Type 1 ON (Optic nerve is adjacent to the sphenoid sinus)



Figure 1c. Optic nerve indentation on the sphenoid sinus on the right (Type 2 ON) and adjacent to it on the left (Type 1 ON)



Figure 2. Cranial axial CT showing bilateral protrusion of the internal carotid artery into the posterior wall of the sphenoid sinus



Figure 1d. Unilateral Type 3 ON (Less than 50% exposure of optic nerve in sphenoid sinus)



Figure 3. Cranial Axial CT. Dehiscent bony wall of the left internal carotid artery with slight focal protrusion (arrow). Note the absence of a complete sphenoid septum.



Figure 1e. Bilateral Type 4 ON (Dehiscence of optic nerves traversing the sphenoid sinus)



Figure 4. Coronal CT through the sphenoid sinus showing bilaterally pneumatized anterior clinoid processes



Figure 5. Cranial coronal CT in bone window showing differential sphenoid sinus sizes with septum located on the right side of the midline



Figure 6. Cranial Axial CT. Protrusion of the right internal carotid into the posterior wall of sphenoid sinus (arrows) on axial CT slice. Note its closeness to the septum

Internal Carotid Artery

Protrusion of the ICA into the sphenoid sinus was identified on the CT images of 30 (27.3%) patients. The right side alone was involved in 9 (8.2%) patients, the left alone in 9 (8.2%) patients and bilateral involvement was seen in 12 (10.9%) patients.

The dehiscence of the bony sphenoidal wall of the internal carotid artery occurred in 12 (10.9%) patients; the right side alone was involved in 5 (4.5%) cases, left side alone in 6 (5.5%) cases and bilateral involvement was seen in 1 (0.9%) case. The CT images demonstrating ICA protrusion and dehiscence of the sphenoid sinus wall around the ICA are shown in figures 2 and 3 respectively.

Pneumatisation of the anterior clinoid process

The anterior clinoid process (ACP) was found to be pneumatised in 16 (14.5%) cases: the right side alone was involved in 4 (3.6%), the left side alone in 8 (7.3%) and bilateral involvement was seen in 4 (3.6%) cases. The CT image of a case of bilateral pneumatised ACP is shown in figure 4.

Sphenoid septum

Absence of sphenoidal septum was found in 3(2.7%) cases in this study. Presence of sphenoidal septum on the right side of the midline was encountered in 29 (26.4%), while that of the left side occurred in 48 (43.6%) cases (figure 5). The sphenoidal septum was situated in the midline in 20 (18.2%) cases while the presence of double sphenoidal septum was documented in only 5 (4.5%) cases. The attachment of the septum to the bony wall of the ICA occurred in 5 (4.5%) cases.

Discussion

Diseases of the sphenoid sinus, sella turcica and para-sella regions abound also in the black African race. Their surgical treatments have great challenges because of the difficult technicalities in approaches to these structures. Endoscopic transnasal sphenoidectomy to treat diseases in the sphenoid sinuses and trans-sphenoidal approach to sella turcica during pituitary surgeries have been successfully performed¹⁴⁻¹⁷. Unlike transcranial approach, endoscopic transnasal sphenoidectomy and trans-sphenoidal approaches are less traumatic, avoid brain retraction and provide better visualization of the pituitary during surgery. A good knowledge of the pattern of pneumatisation of the sphenoidal sinus and a careful characterization of its relationship to vital local and regional neurovascular structures will help to provide guidance to the surgeon during surgery. This will minimize the risk of complications of blindness and severe bleeding which may occur with better treatment outcome.

Optic nerve protrusion into the sphenoid sinus

The preoperative knowledge of ON location in relation to sphenoidal sinus is of great clinical importance in endoscopic sphenoidal surgery. Various studies from different parts of the world have reported varied prevalence rate of ON protrusion from 8% to 70%^{8,9,18}. The reported prevalence of dehiscence of the bony wall between the ON and sphenoidal sinus was 4% by Fuji et al² and 11.7% by Heskova et al⁴. In this current study, the prevalence of ON protrusion into the sphenoidal sinus was 38.2% and dehiscence of the bony wall between the ON and sphenoidal sinus was 15(13.6%) on CT scans of the patients. In this present study, the relationship of ON to sphenoidal sinus and the frequency of occurrence of the Types are shown in Table 1. However, in the study by Batra et al, prevalence of 4.7%, 25.8%, 39.8%, 14.1%, and 15.6% were reported respectively for Types 0, 1, 2, 3 and 4⁸. The difference in values of prevalence rate from different studies might be related to ethnic background. The protrusion or dehiscence put the ON at risk either due to surgical trauma or as a complication of sinus disease. Risk of unintentional and irreversible blindness is considerably high if there is injury to the nerve during sphenoid surgery¹⁹. The high rate of the incidence of ON protrusion into the sphenoid sinus found in this study thus showed the apparent vulnerability of the black Africans to iatrogenic injury like unintentional and irreversible blindness during endoscopic sphenoidectomy or intranasal trans-sphenoidal pituitary surgery. The dehiscence in the bony wall may also contribute to rhinogenic optic neuritis.

Internal carotid artery protrusion into the sphenoid sinus

The importance of ICA protrusion is that it is hardly possible to control bleeding from this vessel if it is injured within the sphenoid sinus. Control of such bleeding often makes neurological sequelae inevitable^{20,21}. In this study, over a quarter (27.3%) CT images of these patients showed protrusion of ICA into the sphenoid sinus and 10.9% showed dehiscence of the bony wall between the ICA and sphenoid sinus. The finding in this study is similar to the study by Sirikçi et al³. However, Fuji et al in their study on 25 cadaveric specimens found 8 % of ICA dehiscence lateral bony wall of the sphenoid sinus² which is slightly lower than the prevalence rate from this study. This protrusion of ICA into the sphenoid sinus and dehiscence of its bony wall as identified on the CT scan of these black Africans,

again, make them theoretically vulnerable to iatrogenic injury with the possibility of uncontrollable and life threatening hemorrhage. This potential risk must be borne in mind during endoscopic sphenoidal surgeries and adequate precaution taken.

Pneumatisation of the anterior clinoid process

Anterior clinoid process pneumatisation can occur concurrently with the ipsilateral ON protrusion. In this study, pneumatised ACP was found in 16 (14.5%) cases and this is similar to the finding from previous studies^{22,23}. However, in 39.1% cases of ACP pneumatisation, concomitant presence of ON dehiscence was also demonstrated. Sirikçi et al however demonstrated concomitant presence of ON dehiscence and pneumatised ACP in 20% of their cases. The varied amounts of pneumatised ACP might be related to ethnic background and also contributed to the varied position and relation of ON to the sphenoid sinus thereby increasing their vulnerability to iatrogenic injury.

Sphenoid septum

In 88.2 % of cases, there was single septum in the midline or on one side of the midline. Double septa were encountered in only 4.5 % cases which is a low rate compared to the findings by Siriki et al³ with a prevalence of 20% and Idowu et al¹³ with prevalence of approximately 50%. The number and location of the septum have surgical importance with regards to the orientation of the surgeon during endoscopic transnasal sphenoidal procedures. Disorientation within the sinus may mislead the surgeon with resultant false passage. The sphenoid septum may be so laterally oriented that it can lie directly over or close to the ICA (figure 6). Such variation was found in 4.5% of the current series. This variation makes the artery vulnerable to iatrogenic injury when there is need to grasp and twist the septum anteriorly at the entrance to the sphenoid sinus during surgery causing forced transmission to the posterior attachment at the level of the internal carotid artery²⁴.

Conclusion

Anatomic variations may be frequently encountered on routine CT examinations in black Africans and it is advisable that radiologists include these variations in their report. These variations are not different from what had been reported in other parts of the world. However, on a more practical surgical note, it is very important that the endoscopic Otorhinolaryngologists or head and neck surgeons managing black Africans should be aware of the relationship of both the ON and the ICA to the sphenoid sinus and the potential risks including blindness, uncontrollable haemorrhage and death that may attend anatomically uninformed surgical dissections in this region. Therefore, there is no gainsaying that preoperative CT reviews by endoscopic sinus and skull base surgeons may reduce surgical complications due to anatomic variations.

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