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Research Paper

The Dimenssion of Sphenoid Sinus in the Adolescence in Enugu Southeastern Nigeria

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ABSTRACT

Introduction

The dimension of the sinus is highly affected by the degree of pneumotization. By the age of 8–10 years, the real sinus cavity is visible, although the definitive cavity will be formed at puberty and the Origin of the sphenoid sinus on the posterior nasal wall can be clearly identified from the location of its ostium1. This developmental pneumatisation continues until adulthood when it reaches the maximum size2. Most authors have recognized three main types of sphenoid pneumatization: concha type, presellar type, and the sellar type. The most frequent type of pneumotization is the sellar type, which appears in 75–86% of cases, followed by the presellar type in 10–25%. The sinus has right and left lateral walls, a roof and a floor including anterior and inferior parts. The pituitary gland is located inside the sellar turcica; this is a round bony cavity that is separated from the sphenoid sinuses by a thin bone, the floor of the sellar, which is part of the roof of the sphenoid sinuses.

MATERIALS AND METHOD:

This is CT scan based clinical anatomical study that was conducted at Memfys hospital for Neurosurgery Enugu. It is a prospective study of the sphenoid sinus morphometry of randomly selected asymptomatic adolescent Nigerians aged between 13 years and 18 years residing in Enugu, Nigerian that met the study criteria. The data was obtained using measurements taken from CT scan of the sphenoid sinus. The statistical analyses was conducted using descriptive and inferential statistics in SPSS 17 version. Ethical approval was obtained for this study.

A prospective, cross sectional, descriptive study designed to measure the anterior-posterior, lateral and vertical dimensions of the sphenoid sinuses in the asymptomatic young adolescent Nigerians aged between 13 years and 18 years that reside in Enugu metropolis and a control from a standardized age related formula for SS volume. These measurements were used in calculating volume of the sphenoid sinus. The mean of the individual values of the sphenoid sinus volume obtained was obtained for each subject, the mean value represents the MSSV value for that subject.

Asymptomatic males and females, who are between 13 years and 18 years old at the time of the recruitments, who had cranial CT scan for traumatic brain pathology order than sphenoid sinus fractures and other non sphenoid sinus brain tumor at Memfys hospital Enugu as at the time of the study.

Non-Nigerians as well as individuals who are already having symptoms related to sphenoid sinus pathology, congenital anomaly of the sphenoid sinus. Also Patients with a previous sphenoid sinus surgery, asymptomatic patients whose CT scan reveals sphenoid sinus pathology and those who met the inclusion criteria but has phobia for CT scan.

A randomized sampling technique to select 104 sample size. The control group was with a matching age related calculated volume using the formula by Yetnusa et al. This included fifty two(52) males and fifty two(52) females. The sample size for the control group was also same.

RESULT

There were fifty-two males and fifty-two females recruited into the study. The mean age for male and females were 15.90 and 16.21 respectively, with average mean age for both gender being 16.08 years. Eliminating gender bias, the right MSSD was revealed to be 19.06 mm in the APD, 16.57 mm in the TD and 17.04 mm in the VD. The SSV_A and the SSV_C are 5.09 mm3 and 28.49 mm3 respectively on the right side. While the left MSSD was likewise shown to be 19.81 mm for APD, 16.82 mm for TD and 16.73 mm for VD. The left SSV_A was noted to be 5.04 mm3 while the corresponding SSV_C was 30.16 mm3.

CONCLUSION:
The role of age in the dimension of SS has been recognized in many literatures. This has been linked with the effect of pneumatization on the dimension of the SS. Thus pneumatizing effect on the SS finally brings about the developmental change seen in the SS as one advances in age. Though age is an important factor in SSD, several studies have found that the age related SS morphometry is not continues process, thus at a certain age limit the changes recorded in the SSD remains almost the same. The importance of SSD has been shown in many studies AS an important factor that guarantees safety during surgical access to the sella region by preoperative screening. This study shows that there is progressive increase in the SSD in the adolescents as the age stratification progresses from 13 to 18 years.

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I. INTRODUCTION

Background of study

Sphenoid sinuses (SS) are the most inaccessible paranasal sinuses and are surrounded by very important and delicate structures such as the orbits with their contents, cavernous sinuses and their contents especially the internal carotid artery and the anterior cranial fossa. Only thin bony structures separate these from the sphenoid sinus[1]. The dimension of the sphenoid sinus has been grossly associated with the extent of the sinus pneumatisation[2]. Variations have been noted of the extent of sphenoid sinus pneumatization. These range from absence of SS pneumatization to extensive pneumatization of the sphenoid sinus. Some authors have implicated this variation in the extent of SS pneumatization as a major factor that may affect the relationship of other structures to the SS. This may have a major impact on the rate of complication during surgical access to the SS[3]. The surgical complications are often encountered during neuro-endoscopic procedures to the sellar/parasellar region. Neuro-endoscopy has grown rapidly in the last 25 years as a diagnostic and therapeutic modality for investigating and treating respectively a variety of brain and spinal disorders[4-6]. Endoscopic trans-nasal trans-sphenoid surgery (ETTS) is increasingly utilized in neurosurgery as first line treatment for most pituitary lesions. These lesions are also present in the adolescent age group requiring the same line of surgical treatment as in the adult population. Thus this study aims to determine the average SS dimension in the adolescent age group since maturation of the SS, which is a function of extent of sinus pneumatization, occurs in the adolescent age group (at puberty) [3]. It is hoped that the outcome of this study will form a guide in the decision to access the sellar region in the adolescent black population in Enugu who have lesions around the sphenoid sinus. The study of the pre-operative CT and MRI scans and perioperative endoscopic visualization can provide useful anatomical information as indicated in sellar, suprasellar, intraventricular (third ventricle), retro-infundibula, and invasive tumors. Recurrent and residual lesions, pituitary apoplexy and empty sellar syndrome can be managed by endoscopic approaches. Modern neuro-navigation techniques, ultrasonic aspirators, ultrasonic bone curette can add to the safety of such operations. These are attainable if the dimension of the SS in the adolescents is known. It is also reasonable enough to say that these endoscope-facilitated procedures are made possible through a well-pneumatized sinus with dimension adequate for the passage of the working tools[7].

Several studies have been done concerning the adequacy of the dimensions of the sphenoid sinus especially in adults and have received wide publications in the literature. In all these studies, detailed knowledge of the dimension of the sinus has been figured out as one of the major factors affecting the success rate in the practice of endoscopic approaches to sellar lesions especially the anatomy of the sinus in relation to neurovascular structures in the parasellar region[8]. Their study of the dimension of the sphenoid sinus in Chinese adult population revealed that the mean distance from the nasal sill to the sphenoid ostium was nearly 66 mm, and that from the sphenoid ostium to the posterior wall of the sphenoid sinus was nearly 14 mm. The angles from the sphenoid ostium to both the carotid artery and the optic canal varied among the patients. The sphenoid ostium was located at almost the vertical midpoint of the anterior wall of the sphenoid sinus. They concluded that from their study the anatomical information obtained about the sphenoid sinus dimension was essential for avoiding complications in performing an endoscopic sphenoidectomy in adults. In Nigeria, a similar study has been done to determine the dimension and extent of pneumatization of the sphenoid sinus in adult blacks aged 18 to 80 years as being noted by Idowo et al, which supports the ongoing discussion. The study of the sphenoid sinus dimension has also been done in several series, with particular interest in the widest anterior-posterior dimension (APD), transverse dimension (TD) and vertical dimensions (VD). The widest dimensions are considered because of the irregular shape of the sphenoid sinus cavity caused by varying degree of the sinus pneumatization and septation[9]. These three parameters: APD, TD and VD as well as age, are essential in calculating the effective volume of the sphenoid sinus. It is this effective volume that is used to determine the adequacy of the SS as a corridor to the sellar region. An in-depth analysis of the role of factors such as age, sex and race in the dimension of SS has been considered in many series and noted to be important contributory factors to the SS dimension. In all the studies CT scan was the image modality of choice.

Computerized Tomography Scan (CT) has been found to be very important tool in assessing dimensions of bony structures, and for preoperative planning of the skull base tumor surgery. This is because of the role of CT scan in identifying bone related lesions in the skull base better than other conventional imaging modalities like magnetic resonant imaging (MRI). After CT image acquisition, 3D reconstruction in sagittal, coronal and axial plane is done and measurements taken accordingly.

Nevertheless, it has to be stated that there is lack of adequate information concerning the dimension of SS in the adolescent population necessitating this study.

Statement of the problem:

In neurosurgery and otolaryngology, several studies have addressed the dimensions of the SS. These studies consistently had the objective of elucidating the surgical anatomy of the SS as the sinus though deeply located in the anterior skull base, serves as an important corridor to this region of the skull base both in the adults and in the adolescents. In the adult population, issues such as pneumatization, septation, location of the SS ostium, neurovascular structures relating to the sinus, age, sex and racial influence have been considered as factors that may affect the sphenoid sinus. All these information properly applied will help the skull base surgeon avoid the attendant complications surrounding sellar and parasellar surgical lesions especially when considering endoscopic approach. In most publications there is appreciable consensus that SS maturity (sellar type/adult size SS) occurs at the age of puberty i.e. between 12 to 14 years and that pnuematization of the various parts of the SS continues upto the third decade of life before declining. Study by Idowu et al. has shown that the APD and the TD of SS are not affected significantly by age within age limits of 18 to 80 years in blacks[9]. Sellar and Parasellar lesions treatable through the trans-sphenoidal route occur in adolescents (13 to 18 years) though the incidence in the adolescents is not yet reported in our environment. Studies have been performed on the anatomy of sphenoid sinus and its dimension in the black adult population (9,24) but not in the adolescent age group. This disparity in the knowledge of the dimension of SS may affect the extent of neurosurgical intervention using this approach in this age group especially endoscopic procedure of the sphenoid sinus. This may be the reason why trans-cranial approaches to this region of the skull base in adolescents have been highly favoured with increasing surgeons` familiarity with high speed drills despite the associated higher complications which include depreciation in the higher cerebral functions, seizure disorders, visual impairment from inadvertent injury to the optic nerve/chiasm, anosmia from damage to the olfactory nerve following frontal lobe extensive retraction/dissection and stroke from vascular accidents affecting speech and ambulation amongst e.t.c.. These conditions often occur during sub-frontal, sub-temporal or pterional tans-sylvian access to the sphenoid/sellar lesions and could be worse in the adolescents when subjected to the risk of trans-cranial surgical morbidity at a tender age. This surgical morbidity may involve cognitive function, speech and ambulation thus affecting their overall wellbeing.

Certain intracranial tumors especially those in the anterior skull base are better handled through endoscopic approach to the cranial fossae. Examples are pituitary adenomas; craniopharyngiomas; fronto-ethmoidal and sphenoid sinus mucoceles provided wide marsupialization could be achieved[10]. In order to overcome these challenges and encourage endoscopic approaches for favourable sellar/parasellar lesion in adolescents, a detailed knowledge of the SS dimension in the adolescents should be acquired and integrated as an important preoperative screening protocol for adolescents with underlying sellar and parasellar lesions. Inferentially, the result of the study could be applicable to adolescents in Nigeria in general

Research Hypothesis:

Ho1. There is no sex difference in the derived values of SSD in adolescents in Enugu

Ha1. There is a sex difference in the derived values of SSD adolescents in Enugu.

Ho2. There is no difference in the average SSD between adolescents rtight and left SS in Enugu.

Ha2. There is a difference in the average SSD between adolescents right and left SS in Enugu.

General Objectives of the Study

This study is aimed at determining the dimension of the sphenoid sinus in black adolescents (13 to 18 years), using Enugu as sample location and CT scan as imaging tool.

Specific Objectives of the Study:

To determine the mean value of sphenoid sinus dimensions (SSDs) in adolescents (13 to 18 years); To compare the mean values of SSDs in male to those in female adolescents (13 to 18 years); To compare the mean SSDs in the adolescents with those in adults (using Idowu’s findings in the adult SSD).

Significance of the study:

The data obtained from these measurements provide reference values for SSDs of adolescents in our patient population. The data will be useful for pre-operative evaluation of adolescents for endoscopic access to the anterior skull base in this population. The data provided may improve the safety of approach to the sellar through this route and may increase the frequency of the approach in this age group

II. LITERATURE REVIEW

Studies have been done on the dimensions of sphenoid sinus in surgical practice especially in adults by neurosurgeons, ear nose and throat (ENT) surgeons and anatomists[11]. Most of these studies were done outside Nigeria with obvious dearth of information on the sphenoid sinus dimensions in adolescents.

Anatomical consideration

Detailed knowledge of the anatomy of the sphenoid sinus is very important in understanding the morphometric changes affecting the sphenoid sinus dimensions. The sphenoid sinuses are formed in the body of the sphenoid bone as a pair of unequal air cavities in the skull base[12]. They are located beneath the boundary of the anterior and middle cranial fossae. The two sinuses are separated by a bony septum, which is rarely in the midline and could vary from single to multiple septae. Each SS opens in a small round hole at the posterior superior end of the nasal cavity at the level of the superior turbinate bone. This sinus develops differently from the other paranasal sinuses. At birth, it arises as a recess between the sphenoid concha and the presphenoid body. Then it starts to develop inferiorly and posteriorly. Part of the sphenoid concha fusses with the presphenoid thus forming the sphenoid sinus cavity in the second or third year of life. The presphenoid recess becomes the sphenoethmoidal recess. After this stage, pneumatization occurs in the presphenoid and the basisphenoid of the sphenoid bone. By the age of 8–10 years, the real sinus cavity is visible, although the definitive cavity will be formed at puberty and the origin of the sphenoid sinus on the posterior nasal wall can be clearly identified from the location of its ostium [13].

This pneumatization continues until adulthood when it reaches the maximum size[14]. Most authors have recognized three main types of sphenoid pneumatization: concha type, presellar type, and the sellar type, while some authors recognize a 4th type as postsellar. The concha type or the fetal-type (fig. 2.1) represents a small sinus, separated from the sellar turcica by about 10 mm of trabecular bone. The presellar type or juvenile type (fig. 2.2) is pneumatized to the level of the sellar turcica. The sellar type (Fig. 2.3) or adult type is pneumatization of the sphenoid below the sellar or further posteriorly [12, 14]. The most frequent type of pneumatization is the sellar type, which appears in 75–98% of cases, followed by the presellar type in 10–15%. The concha or fetal type is usually found in ≤2% of cases[15]. Pneumatization of the sphenoid can extend in all its components, like the greater and lesser wings, the pterygoid plates, and the basiocciput. The sinus spreads more often anteriorly and laterally then posteriorly and inferiorly[16]. These extensions of the sinus bring it in close relations to vessels and nerves of the skull base.

The sinus has right and left lateral walls, a roof and a floor including anterior and inferior parts. The pituitary gland is located inside the sellar turcica; this is a round bony cavity that is separated from the sphenoid sinuses by a thin bone, the floor of the sellar, which is part of the roof of the sphenoid sinuses[17]. Other important bony structures of the roof of the sinus starting from the sellar turcica are: the optic groove across the anterior part of the turcica which is separated from it by the tuberculum sellae as it contains the right and left optic nerve forming the optic chiasm just anterior to pituitary stalk. The chiasm has been described by several authors as being in prefix, normal or postfix positions in respect to sellar turcica; the tuberculum sellar which spreads out bilaterally as the optic strut, it is this strut that separates the optic canal/optic groove superior laterally from the carotid cave inferior laterally. Antero-superior to the optic groove is the limen sphenoidal which marks the posterior extent of the planum sphenoidae. The right and left anterior clinoid processes are posterior lateral extension of the planum sphenoidae as it meet with sphenoid ridge. The inferior part of the anterior clinoid process is in connection with the optic strut. The rectus gyrus lie medially on the planum sphenoidae while the olfactory nerve in its groove lies lateral to it. In sellar or post sellar pneumatization of the sphenoid sinus, the dorsum sellae that lies posterior to the pituitary gland at the summit of the clivus could be the most posterior part of the roof of the sinus. Many authors have assessed the relationship of optic nerve in the superior part (roof) of the sphenoid sinus. The most commonly used description pattern of the various anatomical relations of the SS and the optic nerve is the classification system by Delano[18]. Which follows thus:

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

On either side of the sphenoid sinus, are located a pair of intercommunicating venous channels (caverns) called the cavernous sinus. The connections between the two cavernous sinuses on the lateral wall of the SS has an anterior and posterior parts know as the anterior and posterior intercavernous sinuses which run on the roof of the SS around the pituitary stalk as the circular sinus. This could be a source of profuse bleeding during ETT procedures in the sellar region. The anatomy of the sphenoid sinus is such that several important structures pass through the cavernous sinus between the venous channels: - The internal carotid artery and the abdusence nerve medially (V1), the ophthalmic division of the trigeminal nerve (V_1), the maxillary division of the trigeminal nerve (V_2), the oculomotor nerve (III), the trochlear nerve (IV) on the lateral wall of the cavernous sinus, and the sympathetic chain in relation to the cavernous segment of the internal carotid artery as shown in (Fig 2.4). Occasionally, the ophthalmic artery (in about 2%) can arise from the cavernous segment of the internal carotid artery The relation of the above-mentioned vascular and nervous structures to the ossification centers of the sphenoid body explains their close relations to the sphenoid sinus. The mucous membrane receives sensory innervation by the posterior ethmoidal nerves, and postganglionic parasympathetic fibers of the facial nerve that synapsed at the pterygopalatine ganglion. Sometimes, the bony wall separating the internal carotid artery from the sphenoid sinus is very thin or absent. In such cases, the carotid is seen pulsating in the lateral wall of the sphenoid sinus. In lesions such as hardy type 11E pituitary adenoma, where the tumor has extended into the parasellar region, Knosp has graded the relationship of this tumor as it invades the intracavernous carotid artery. In principle, out of the structures in the lateral wall of the sphenoid sinus, the internal carotid arteries and the optic nerve are the most at risk during trans-sphenoidal surgery especially of lesions in the parasellar region.

The anterior part of the SS is bordered by the ostium of the sinus and is in direct relation with nasopharyngeal structures and it contains the spheno-palentine vessels. Many authors have described the posterior wall as being bordered by the clivus, which separates it from the ponto-mesencephalic and the prepontine cistern and their content especially the basilar artery, its pontine branches and the pons. The floor has the downward projection of the pterygoid processes bilaterally. The floor of sphenoid sinus is occasionally composed of ridges covering the pterygoid canal through which the vidian nerve passes. This vidian nerve is composed of the sympathetic fibers from the deep petrosal nerve and the parasympathetic fibers from greater petrosal nerve. This nerve gave autonomic supplies to the spheno-palatine ganglion at the floor of the sphenoid sinus.

Factors affecting SSD

Extent of pneumatization

The role of pneumatization on the anatomy of the SS especially as it concerns the neurovascular structures in relation to the SS has been adequately studied. One of such study by Fasunla et al. was based on the relationship of optic nerves and internal carotid in a well-pneumatized SS. It was a retrospective study using both the coronal and the axial CT reconstructed images of the paranasal sinuses and brain of 110 patients which were obtained for head and neck diseases other than malignancies, nasal polyp and craniofacial trauma. Their study, which was based in a black African population, revealed that forty-two (38.2%) cases have optic nerve (ON) protruding into the sphenoid sinus and ON wall dehiscence occurred in 15(13.6%). Protrusion of the internal carotid artery (ICA) into the sphenoid sinus was on CT images of 30 (27.3%) patients and dehiscence of bony sphenoid sinus wall of ICA occurred in 12 (10.9%) patients. The anterior clinoid process (ACP) was pneumatized in 16 (14.5%) cases and sphenoid septum was absent in 3(2.7%) cases. They concluded that anatomic variations exist in relationship of sphenoid sinus to ON and ICA as seen on CT examinations in black Africans population and advised that 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 sphenoid sinus surgeries[19]. This study shows how important the degree of pneumatization of SS is, as it can affect the effective volume (volume adequate for endoscopic trans-spheniodal access to the sellar region) of the SS in the black population. Given that the protrusion and dehiscence of the wall of the SS by OP and ICA could be as high as quoted above and could limit the endoscopic approach to the sellar region, as a direct effect of pneumatization of the SS, it does show that in the presence of large volume or dimension of the SS the SSD could still be regarded as ineffective or inadequate as a corridor to the sellar region. Also Sinuses with sellar/postsellar pneumatization have been considered to be technically less demanding for a trans-sphenoidal hypophysectomy as compared to the presellar pneumatization because they have adequate dimension.

The dimensions of the SS is highly affected by the degree of pneumatization as noted above and form the bases of classification of the SS into three main types. Most scholars of skull base anatomy believe that the sellar type of sphenoid sinus is well pneumatized with bulging of the sellar floor into the sinus while the presellar type of sinus is situated in the anterior sphenoid bone and does not penetrate beyond the perpendicular plate of the tuberculum sellae. In cases of extensive pneumatization, the maxillary nerve may bulge into the lateral wall of the sphenoid sinus. In extreme cases, the nerve may be entirely surrounded by pneumatization. However, arrested skull base pneumatization is an anatomic variant that most commonly occurs in sphenoid sinus. This is diagnosed as non-expansive lesion at a site of normal or accessory sphenoid sinus pneumatization. Here the lesion has sclerotic margins, internal fatty content and curvilinear internal calcifications. It should preserve the margins of associated neural foramina. These constellations of findings confirm the diagnoses of arrested pneumatization. Occasionally these criteria may not be fully present necessitating serial imaging follow–up to confirm benignity. The Ostia of the sphenoid sinus are usually located in the spheno-ethmoidal recess, directly medial at the level of the superior turbinate where they can usually be seen well with the endoscope. The anterior wall is connected to the perpendicular plate of the ethmoid and vomer in the midline and has to be fractured to enhance access to the pituitary fossa during endoscopic trans nasal Transsphenoidal (ETT) approach in the neurosurgical treatment of sellar, parasellar, and suprasellar tumors.

The floor of sphenoid sinus is occasionally composed of ridges covering the vidian nerve. The medial and superior walls are usually smooth and the superior wall may balloon outwards from pressure of the sella tursica. The variation in size and shape of two sphenoidal sinuses contained within the body of the sphenoid bone is due to the lateral displacement of the intervening septum, thus they are rarely symmetrical. When exceptionally large, they may extend into the roots of the pterygoid processes or great wings, and may invade the basilar part of the occipital bone 18, 20,

Role of age, sex, race and onodi cells on SSD

The role of age, sex, race and other morphometric variables such as Onodi air cells as they affect the dimension of the SS have been widely discussed in the literatures.

The SSD has been unequivocally noticed to be variable among various age groups, sex and race. The role of Onodi cells as a factor influencing the dimension of SS has been evaluated in details[21]. In Chinese population, Wu HB, et al. on the sphenoid sinus, did a study. They used sagittal reconstructed images obtained from 178 CT images of 89 cases of normal adult participants (54 males and 35 females) to study the effect of age, sex and race on the sphenoid sinus dimension. They took the high-resolution axial CT images from all the subjects of the thickness 0.625 mm, and reconstructed 1-mm-thick gapless sagittal CT images to measure the distance of all the sellar and pre-sellar types on the three-dimensional sagittal plane in the bone window (4,000 at its width, and 400 at its level) in the CT images. The length of mean vertical line from the center of sphenoid ostium to the roof of sphenoid sinus of non Onodi cell type was noted to be 10.6 ± 1.5 mm, and of Onodi cell type is 3.3 ± 1.5 mm. The length of vertical line from the center of sphenoid ostium to the lowest level of the bottom of sphenoid sinus was 12 mm ± 3.7 mm. The length of mean horizontal line from the sphenoid ostium to the posterior wall of sphenoid sinus was 18 ± 1.5 mm or 28 ± 2.5 mm. The mean horizontal line from the lowest point of the sellar to the anterior wall of sphenoid sinus was 17.5 ± 1.3 mm in length. The mean horizontal distance from anterior wall to posterior wall of sphenoid sinus of Non Onodi cell type lining skull base is 10.1 ± 1.0 mm, and of Onodi cell type, was 5.2 ± 4.3 mm. While the longest horizontal distance from the anterior wall to the posterior wall of sphenoid sinus was 22.0 ± 7.7 mm. This study provides anatomical information about sphenoid sinus of the Chinese in Asia with some surgical distance measured between the sphenoid ostium and the surrounding structures. This study shows that the presence of Onodi air cells compromised the dimension of the SS in the Chinese population whereas in Nigeria, sex, though not very significantly, was the main factor in the black population as noted by Idowu et al. However it must be pointed out that the study by Wu BH et al . has shown that even in the presence of Onodi air cells, the measurement of the dimension of the SS can still be done with the dimension not being affected provided the measurement is taken from a certain anatomical land mark. First they noted that there was a reduction in the mean horizontal distance from anterior wall to posterior wall of sphenoid sinus by 4.9 mm in the Onodi air cell type of SS, the second point they noted was that the length of mean vertical line from the center of sphenoid ostium to the roof of sphenoid sinus of Onodi cell type was reduced by 7.3mm but the dimension was not affected when the measurement was taken from the center of the ostium to the lowest point of the bottom of the SS. This means that in considering the effect of Onodi air cells on the SS anatomy, for accurate measurement of the SSD especially in Asians, certain anatomical landmarks have to be chosen to obviate this limitation. This is more so since the SS is not a uniformly formed cavity. The study by Wu BH et al shows that such anatomical landmarks may include the following: The length of vertical line from the center of sphenoid ostium to the lowest level of the bottom of sphenoid sinus, the length of mean horizontal line from the center of sphenoid ostium to the posterior wall of sphenoid sinus, the mean horizontal line from the lowest point of the sella to the anterior wall of sphenoid sinus, the transverse diameter of the SS cavity and the longest horizontal distance from the anterior wall to the posterior wall of sphenoid sinus.

Racial variation may not directly affect the dimension of the SS. However the presence of various degree of dehiscence and protrusion of the lateral wall of the SS by optic nerve and the carotid artery may suggest an indirect effect. The same view may be extended to the presence of Onodi air cells. While the later has not been proven, the former has. Sareen, D et al suggest strong possibilities of racial variations in terms of relationship of the internal carotid artery and optic nerve to the sphenoid sinus in the Indian population. Senja, T et al. did a study on the anatomic variations in sphenoid sinus pneumatization between Asians and Caucasians and concluded that there exists, a statistically higher prevalence of internal carotid artery protrusion in Caucasians compared with Africans Americans and Hispanics, as well as statistically higher prevalence of optic nerve protrusion in Caucasians and Asians when compared with African Americans and Hispanics[25]. These findings may have interesting implications when considering the ease of assess to the SS in endoscopic trans-sphenoidal procedures and complication rates among different ethnic groups, and by extension the effective SSD.

Similarly, the comparative study of the SSD between the Chinese and the Caucasians by Yuntao L et al. showed that extended pneumatization of the sphenoid sinus SS which inadvertently increased the SSD is an indispensable element for the extended trans-sphenoidal (ETS) approach[26]. Because most anatomical studies of the ETS approach use Caucasian subjects, their study aimed to clarify the pneumatic extension types in Chinese individuals as well as any differences from those in Caucasians and analyze these differences with respect to the application of the ETS approach. A total of 200 computed tomography (CT) images of SSs and 18 adult cadaveric heads were selected for observation and measurement. The conchal, presellar, and sellar types comprised 6, 28.5, and 65.5% of subjects, respectively; according to the extra extension, the prevalence of the lateral, clival, lesser wing, and combined extension sinus types was 11.4, 21.4, 0.8, and 48.1% of subjects, respectively. The percentages of pneumatization of the anterior and posterior clinoid processes, pterygoid process, and optic strut were 5.0, 1.0, 22.3, and 7.0%, respectively. Onodi cells were observed in 61.1% of the SS of the cadaveric heads, including 30.6% with good pneumatization with identifiable optical or ICA bulges. They commented that these features were related to poor lateral and clival pneumatization in Chinese compared with Caucasians, which might make extended surgery more dangerous. However, the anterior pneumatization, especially the higher presentation of Onodi cells, ensures that the anterior ETS approach can be performed safely in Chinese patients. In general, measurements showing smaller sinus volumes and thicker bones with identifiable bone landmarks that are hard to find compared with those in Caucasians suggested increased surgical risks in the Chinese population. Their study shows how grossly important the detailed knowledge of SSD is, especially in considering the various anatomical variations in different races caused by variation in pneumatization and how this variations can be taken advantage of during the preoperative CT scan planning of trans-sphenoidal approaches to the sellar region.

Dimensions Of SS

One of the important parameters in measuring SSD is the volume of the SS though it is difficult to decide the best way of accurately measuring the SS volume (SSV), considering the irregular shape of the deeply sited sinus and the various extent of its pneumatization. It has been recognized that aeration of the SS expands with the development of the sphenoid bone, but there is existence of scant detailed volumetric data regarding this process, as it evolves from childhood to old age[22]. Yonetsu et al, using helical CT scanning were able to assess age-related volumetric changes of the SS. They used CT data obtained from 214 patients (age range, 1 to 80 years; 111 male and 103 female subjects) who had middle or inner ear disease to assess the extent of SS aeration. They accomplished this by determining the volume of SS of 1.0 mm or 1.5 mm reformatted images by integrating the sinus air (~900HU) area. Their result revealed that SS aeration began as a doublet in the anterior boundary of the sphenoid bone by the age of 5 years, with patients more than 6 years exhibiting varying degree of aeration, that the aeration on both sides continued to expand until the third decade of life. They also found out that the maximum average volume was 8.2 +/-0.5 cm3, after which the SSV decreased gradually with average volume in the seventh decade of life being 71% of the maximum level. They also reported that the aeration of the peripheral portions of the sphenoid bone, such as the pterygoid process, anterior clinoid process, and dorsum sellar, occurred mainly after closure of the spheno-occipital suture and showed tendency to recede during aging. Their patients were followed up with three-dimensional CT images, which clearly delineated the development of the sphenoid sinus. Thus, the vertical sphenoid sinus septum persisted throughout the expansion and subsequent reduction in aeration. No significant difference in volume between men and women in any age group was demonstrated in their study.

This study of determinations of sphenoid aeration volume supported the concept that the sphenoid aeration expands and then recedes with age; the volume of sphenoid aeration increased until the third decade of life even though its maturation has occurred at puberty (12 to 14 years). Thereafter, the volume reduced with age. It is because of this various shapes of the cavity of the SS due to its developmental peculiarities resulting from variation in pneumatization between one individual and the other that the limitation in accurately calculating SSV from the anterior posterior, vertical and transverse dimensions APD, VD and TD respectively exist. However, Yonetsu et al have associated age of an individual with his or her SSV without gender or racial bias by noting that the sphenoid sinus volume (Vcm3) at a particular age (A = years), could be estimated by the following formula: ($V = - 2.23 + (0.77A– 0.018 A^2 + 0.00012A^3)(r =0.69)$). They used a paired t-test to analyze the difference in the volume of sphenoid aeration between female and male patients in each of the age groups. Then using a polynomial regression analysis for age-related changes in the sphenoid aeration volume, they fitted the obtained data into an equation of third degree as noted above. Their analyses were performed with Stat View 4.0 software (Abacus Concepts, Berkeley, CA). Their study has shown that sinus aeration on both sides seemed to manifest independently throughout development and, at maturation, the volumes of bilateral aeration differed markedly in many cases. Their work also shows that irrespective of the sphenoid sinus APD, VD and TD at any particular age, the SSV could be calculated using only the value of the patient's age.

However, in the case of the study of the SSD by Sareen, D et al, the anterio-posterior diameter of the sinuses ranged from 1.3 to 3.4 cm (mean=2.5 cm). Transverse diameter of the sinuses ranged from 1.2 to 5.0 cm (mean=2.8 cm). Vertical dimension ranged from 1.4 to 3.6 cm (mean=2.2 cm). Volume ranged from 3.0 to 10.0 ml. (mean=5.8 ml). They measured other dimensions such as from midpoint on anterior wall of sphenoid sinus that ranged from 0.1 to 0.4 cm (mean=0.2 cm). From the base of sphenoid ranged from 0.6 to 2.2 cm (mean=1.6cm. From anterior end of superior turbinate ranged from 0.8 to 2.6 cm (mean=2.2 cm), but no Onodi cells were identified and no gender bias was recognized[23]. In their study, they identified two kinds of sphenoid pneumatization patterns, i.e., presellar (25% of sinuses) and postsellar (75% of sinuses).

Nevertheless, multiple intersinal septae were found in 80% of the sinuses in their study. This is similar to an earlier study by Elwany et al. in which 73% sinuses had multiple septae that were not necessarily midline. This signifies that where intersinal septum exists they cannot be used as a reliable guide to the midline during measurement of SSD or even in sinus surgery because the course of the septum is not necessarily central and can affect the actual dimension of the SS. It frequently deviates laterally and superiorly in its posterior course and inserts into the bony bulges over the optic nerve or the internal carotid artery. This information becomes handy during screening of candidate for study of the SSD.

The average volume of the sinus in their study was 5.8 ml. It has been estimated to be about 6 to 7.5 ml. In the series of Yonetsu et al, it was noted to be 8.2mls though their study was not stratified into presellar and sellar sinuses. in the series by Elwany et al, the average SSV of presellar sinus was 2.5 ml[24] and it was 8.5 mls. for postsellar sinuses. The average dimensions were found to be: anterior-posterior 3.1 cm, transverse-1.9 cm and vertical-2.6 cm. The ostium of the sinus was found to be 0.2 cm from the midline, 1.6 cm above the floor of the sphenoid sinus and 2.2 cm from the anterior end of the superior turbinate on an average. The ostium was located at the levels ranging from 10 to 20 mm above the sinus floor. There was no gender or age bias in their study in adult population. No comment on Onodi cells was noted.

The effective SSD is very important when measuring the SSD because it is the dimension that guarantees safety during clinical assessment of the SSD for ETT. This is very true because the course of the neurovascular structures surrounding the SS may limit the corridor to the sellar/parasellar lesions even when the measured SSD is capacious enough. This means that a balance has to be struck between the measurement of SSD obtained without considering their neurovascular relationship and the measured SSD with consideration of the neurovascular surroundings (effective SDD).

Role of SSD in Endoscopic transnasal transphenoidal surgery:

The endoscopic trans nasal trans-sphenoidal approach to sphenoid sinus is a technique, which has established itself in the recent years and demands a thorough knowledge of the surgical anatomy and a huge amount of anatomical variations (especially with the dimensions) involving the sphenoid sinus. In the black population, especially in Nigeria, Idowu OE, et al. did a prospective study of the sphenoid sinus morphology using the cranial tomographic (CT) scan images of 60 Nigerian adult patients. The CTs were reviewed regarding the different anatomical variations of the sphenoid sinus: dimensions, septation, and pattern of pneumatization. There were 37 males and 23 females. The patients' ages ranged from 18 years to 85 years, with a mean of 47.2 years. There was a main single intersphenoid septum in most patients (95%). The insertion of the septum was usually to the right posteriorly (38%) and in the midline anterior (65%). Although there was consistently a main septum, the septa present were multiple in 29 of the sinuses studied. There was no gender difference with respect to the attachment of the main sphenoid sinus septum. The sphenoid anterior-posterior, and transverse dimensions were not significantly dependent on age, but they were longer in males than in females with average total of 23.8 mm and 26.0 mm for right, then 18.6 mm and 20.1 mm for left respectively. Sellar type pneumatization was present in the majority of the patients (83%), with 4 patients having postsellar (sellar) pneumatization (6.7%) and 3 patients having presellar pneumatization (5%). There were no cases with concha pneumatization or lateral pneumatization of the greater wing of the sphenoid. They concluded that the study provides anatomical information about the sphenoid sinus dimensions and morphology that is essential for avoiding complications in performing an endoscopic sphenoidotomy in adult black.

Their study noted that the sinus anterior-posterior and transverse dimensions were not significantly dependent on age but the same could not be said of the vertical dimensions within the study group. They also noted male gender bias. The SS lateral wall penetration by the neurovascular structures was not recorded in any of their subject thus they noted that the mean dimensions were satisfactory for endoscopic trans nasal transphenoidal procedures in adult black. But failed to compare racial influence on the SSD.

Role of CT scans in SSD

The use of CT scan in assessing the dimensions of sphenoid sinus has been the gold standard[27]. This is because of its ability to highly delineate the bony structures of the skull base with the bones appearing hyperdence (white) and with air appearing hypodence (dark) to cortical matter. Slice thicknesses ranging from 1 to 5 mm are used to acquire bone and soft tissue windows in coronal and axial planes. CT scan was employed as a veritable tool in all the series of studies done in the sphenoid sinus probably because it offers reliable anatomical references, providing quantitative and qualitative analyses of the sphenoid structures. The fundamental principle behind radiography is the following statement: CT scan uses x-ray beam to produce image of the targeted structure. X- rays are absorbed to different degrees by different tissues. Dense tissues such as bone absorb the most x-rays, and hence allow the fewest passing through the body part being studied to reach the film or detector opposite. Conversely, tissues with low density (e.g. air and fat) absorb almost none of the x-rays, allowing most to pass through to the film or detector opposite. Conventional radiographs are two-dimensional images of three-dimensional structures; they rely on a summation of tissue densities penetrated by x-rays as they pass through the body. It should be noted that in plain radiographs, denser objects, because they tend to absorb more x-rays, could obscure or attenuate less dense objects. However, with CT scanning an x-ray source and detector, situated 180 degrees across from each other, move 360 degrees around the patient, continuously detecting and sending information about the attenuation of x-rays as they pass through the body. Very thin x-ray beams are utilized, which minimizes the degree of scatter or blurring that limits conventional radiographs. In CT, a computer manipulates and integrates the acquired data and assigns numerical values based on the subtle differences in x-ray attenuation. Based on these values, a gray-scale axial image is generated that can distinguish between objects with even small differences in density. Some important factors such as atenuation coefficient windowing and artifact may compromise the quality of the CT scan report if not properly understood. The tissue contained within each image unit (called a pixel) absorbs a certain proportion of the x-rays that pass through it (e.g., bone absorbs a lot, air almost none). This ability to block x-rays as they pass through a substance is known as attenuation. For a given body tissue, the amount of attenuation is relatively constant and is known as that tissue's attenuation coefficient. In CT, these attenuation coefficients are mapped to an arbitrary scale between 1000 HU (Hounsfield unit) (air) and +1000HU(bone). This scale is the Hounsfield scale (in honor of Sir Jeffrey Hounsfield, who received a Nobel prize for his pioneering work with this technology). Windowing allows the CT scan reader to focus on certain tissues within a CT scan that fall within set parameters. Tissues of interest can be assigned the full range of blacks and whites, rather than a narrow portion of the gray scale. With this technique, subtle differences in tissue densities can be maximized. The image displayed will depend on both the level of the viewing window and the width of the window. Most CT imaging includes windows that are optimized for brain, blood, and bone. CT of the cranium is subject to a few predictable artifactual effects that can potentially inhibit the ability to accurately interpret the images. Besides motion and metal artifact, the two most common effects are called beam hardening and volume averaging. It is important to understand these effects and to be able to identify them, because they can mimic pathology as well as obscure actual significant findings during measurement of SSD.

Beam hardening is a phenomenon that causes an abnormal signal when a relatively small amount of hypodense brain tissue is immediately adjacent to dense bone as in the case of small pituitary gland in the sella turcica of a presellar type of SS (with thick sellar roof). It appears as either linear hyper-or hypo densities that can partially obscure the cavity of the SS. Although beam hardening can be reduced with appropriate filtering, it cannot be eliminated. Volume averaging (also called partial volume artifact) arises when the imaged area contains different types of tissues (e.g., bone and brain). For that particular image unit, the CT pixel produced will represent an average density for all the contained structures. In the above instance of brain and bone, an intermediate density will be represented that may have the appearance of blood. As with beam hardening, certain techniques can minimize this type of artifact (e.g., thinner slice thickness, computer algorithms), but it cannot be eliminated completely. When over used, CT scan can predispose us to radiation hazard especially in younger age group. We all are exposed to 1.5mSv (millisieverts) of radiation every year by the sun, and CT scans machines expose us to a dose in the range of 1 mSv to 15 mSv. Radiation dose of a CT scan increase dramatically depending on which part of the body is being examined and the techniques used. In the literature it is noted that in CT scan of the head, 1.4 mSv is required, which corresponds to seven-and-a-half month's background radiation. The chances of cancer increase by 0.04 percent. The estimation is based on the survey of the Royal Australian College and New Zealand College of Radiologist. The age and sex of the patients matter a lot because young cells of children and breast tissue of women are more sensitive to the CT scans radiation. Higher level of radiation may increase the possibilities of cancer but at lower level, dose risk is more difficult to identify. The type of CT scan machine and the body size have also been implicated in the radiation hazard risk as the risk is higher in the obese and in smaller slide CT scan e.g. 4 slide > 8 slides CT. Thus in measurements of the SSD in the adolescents, 1.4 mSv should be targeted and thin slides should be obtained using helical protocol to reduce the duration of radiation exposure.

The Adolescence:

The adolescence has been defined as a transitional stage of physical and psychological human development generally occurring during the period from puberty to legal adulthood (age of majority)26 . This could be extrapolated to range from 13 years to 18 years coinciding with age of puberty to adulthood respectively in Nigeria. The clearest understanding of the SSD in this group may enhance knowledge of the sinus morphometry and thus provide scientific bases for further studies in identifying the limits of surgical dissection and hence the effective application of endoscopic approaches to the sellar region in the targeted group especially in Nigerians from Southeastern region.

Following the on going discussion, it has been established that at 8 to 10 years of age the sinus cavity is already visible and the definitive cavity is formed at puberty. Pneumatization continues up to the third decade of life even when it completes its maturation at the age range of 12 to 14 years. However, adequate information on the dimension of the sphenoid sinus in the adolescent age group has not been established even though there is an existence of a persuasive prelude. This may be due to the fact that the sphenoid sinus morphometry continues in the adolescent age group but the knowledge as to whether the dimension attained at this age group is satisfactorily comparable with the adult's remains elusive. Following the embryologic development of the sphenoid sinus, it is expected that at puberty the actual cavity and dimension of the SS has taken place but studies have not been carried out in our environment as to what the actual mean dimension of the SS is in the adolescent black Nigerians especially in southeastern part of the country. Thus this portrays a gap in knowledge concerning the dimension of the sphenoid sinus in adolescence especially in the black.

III. MATERIALS AND METHOD

This is CT scan based clinical anatomical study was conducted at Memfys hospital for Neurosurgery Enugu. It is a prospective study of the sphenoid sinus dimension morphometry of randomly selected asymptomatic adolescent Nigerians aged between 13 years and 18 years who are from southeastern part of Nigeria that meet the study criteria. The choice of this age range is because the emphasis in this study was directed entirely at normal adolescent sphenoid sinus with sellar/postsella type pneumatization. The data was obtained by using measurements taken from CT scan of the sphenoid sinus by the researcher. The statistical analyses was conducted using descriptive and inferential statistics. Ethical approval was obtained for this study.

This is a prospective, cross sectional, descriptive study that was designed to measure the anterior-posterior, lateral and vertical dimensions (APD, LD and VD) respectively of the sphenoid sinuses in the asymptomatic adolescent Nigerians aged between 13 to 18 years who are from southeastern part of the country. The calculated volume of their sphenoid sinus (SSV) was determined and used as a control for that age. The mean of the individual values of the sphenoid sinus volume SSV were obtained. This mean value represents the MSSV value for the adolescents. The study was carried out in Enugu metropolis using CT scan facilities at Memfys Hospital for neurosurgery. Memfys hospital is one of the major neurosurgery referral Centre in Nigeria especially the Southeastern part. The Centre has two sets of ultramodern CT scanning machines (Ceretom^R portable 8-slice head and neck CT scan machine, model number NL 3000, software WS 01.02 and Philip, Brilliance 64 CT Scanner) amongst other neuro-diagnostic armamentarium. As a research based neurosurgical institution, the MHN Enugu has the services of several highly qualified neurosurgeons, radiologists, radiographers and data processing unit. The Centre is certified by the Nigerian radiation safety in diagnostic and interventional radiology regulation board. Thus the neuro-diagnostic division of the hospital is highly patronized. These factors are necessary to facilitate the conduction of the research at a minimum cost, safely and with a good coverage of the population size.

The population of study was made up of adolescents between 13 years and 18 years in the southeastern part of Nigeria within Enugu metropolis, though the actual current population of adolescents in Enugu within this age group has not yet been published.

The study group was made up of randomly selected consenting (consent was obtained from the parents or caregivers of the minors) asymptomatic adolescent males and females, between the ages of 13 years and 18 years, who are from southeastern Nigeria, who attended to at MHN Enugu for health conditions order than sphenoid or parasella lesions, and who needed cranial CT scan for brain pathology order than skull base tumors during the time of the study. Also asymptomatic adolescent males and females, between the ages of 13 years and 18 years who came to the MHN Enugu with their parents at the time of the study, and whose parents consented to their wards participating in the study were recruited for the study.

This study was conducted in a sample population of asymptomatic male and female adolescents aged between 13 and 18 years, resident in Enugu and who have no pathology involving the sphenoid sinus. The following anatomical dimensions of the sphenoid sinus measured:

- The widest anterior-posterior dimension from the sphenoid ostium to the posterior wall of the sinus (APD)
- The maximum transverse diameter (TD)
- The maximum vertical diameter (VD)
- The calculated average volume of the sphenoid sinus (SSV)

Asymptomatic male and female adolescent Nigerians, who are between 13 years and 18 years old at the time of the recruitments whose parents or caregiver consented to the study and came to MHN Enugu as at the time of the study. Patients who had cranial CT scan for traumatic brain pathology order than sphenoid sinus fractures and other non-sphenoid sinus related obstructive brain lesions at Memfys hospital Enugu as at the time of the study. These groups were adolescent Nigerians, who are between 13 years and 18 years old as at the time of the recruitments.

Non-Nigerians and Nigerian adults as well as adolescents who were already having symptoms related to sphenoid sinus pathology (example: SS mucoceole, osteosarcoma of the SS bone, pituitary tumor, fracture, etc.). Also patients with a previous sphenoid sinus surgery, and asymptomatic patients whose CT scan reveal sphenoid sinus lesions were excluded from the sample size.

In order to draw a sample for the study, random sampling procedure will be used to select candidates from the study population constituting one hundred consented patients (100) in the sample size. These will include the adolescents between the ages of 13 to 18years who are from southeastern Nigeria who will present to MHN Enugu for reasons requiring CT scan and satisfied the inclusion criteria. Also adolescents within the stipulated age range that meet the inclusion criteria, who presented to MHN Enugu for other reasons not relating to CT scan but whose parents or caregivers consented to the research, will be recruited. Fifty percent (50%) of these will be male while the remaining will be female adolescents. In choosing the participants in this study care will be taken to in minimize radiation risk to the sample group not requiring CT scan imaging by selecting minimum radiation dose enough to successfully carry out the study.

The sample size for scientific studies is dependent on three factors: (i) the estimated prevalence of the variable of interest, (ii) the desired level of confidence and (iii) the acceptable margin of error. In an infinite population the sample size is usually calculated using the formula: $n = z^2 \text{ X } p \text{ X } (1\text{-}p) / d^2$. Where n is the desired sample size, z is the standard normal deviate which reflects the confidence level at 95% set as 1.96, p is the percentage of the population with the condition (which in this study represented the percentage of adolescents with measurable pneumatized SS {sellar and presellar type) noted to be about 98%}, and d is the degree of accuracy or confidence interval often set as 0.05.

The result from the above formula gave a sample size approximately 99 participants. However, in order to obviate due contingency like error in recording, the sample sias increased by 5%(~5) making a total of 104 participants.

Therefore, the total minimum number of adolescents expected to participate in this study is one hundred and four (104). This included fifty two (52) males and fifty two (52) females.

The potential participants were recruited randomly by word of mouth following a brief interview by a dedicated staff at the CT scan reception or by the researcher. The individuals who met the inclusion criteria for this study were further be interviewed by the researcher using a structured questionnaire to rule out any exclusion criteria (see Appendix 1). All participants` parents or caregivers signed a written informed consent before participating in this study (see Appendix 2)

A designated radiographer perform all imaging; CT scan of the brain. They were positioned supine on a spine board for the CT scan. The radiation level was targeted at 1.4 mSv. The Head position was standardized such that the lateral canthus of the eye and the top of the tragus formed a line perpendicular to the horizontal. High-resolution axial CT images from all the participants of the thickness 1.5 mm, Slide image time of 14 seconds obtained with 8 slides CT scan were performed. This was sreconstructed with 4mm-thick gapless sagittal, coronal and axial CT images to measure the distance of all the SSD on the three-dimensional reformatted sagittal, coronal and axial planes under the bone window (4,000 at its width, and 400 at its level) in the CT images.

Thus to test the measurement errors, Six participants (three males and three females) had both CT scans of the sphenoid sinus, a consultant neurosurgeon or radiologist took measurement of the SS of the six participant's SS three times each to evaluate inter-observer errors. Then measurements were repeated one week later by the consultant to evaluate intra-observer errors. This helped to confirm that the CT scan measurement software was accurate and reliable

After the cranial CT scanning was completed. Measurement were obtained from 3D reconstructed images in sagittal, axial and coronal planes as follows: Sagittal reconstruction for anterior–posterior dimension (measurement taken from the sphenoid ostium to the inner lining of the posterior wall of the sphenoid sinus noted as APD), Axial reconstruction for transverse dimension (measurement taken from the inner lining of one lateral wall of the sinus to the other, in the case of absence of middle septum or from the middle septum to the inner lining of the lateral wall noted as TD), Coronal reconstruction for vertical dimension (measurement was taken from the inner lining of the roof to the inner lining of the floor of the sphenoid sinus noted as VD). All measurements will be in millimeters and taken from the points of widest dimension. All measurements were taken by a dedicated properly trained person (the researcher) using the digital caliper in the CT scan computer software. Measurements performed two times before the data were averaged, and to obviate an intra observer error, either a consultant neurosurgeon or a consultant radiologist working at the institution, repeated the measurement in randomly selected sample. These measurements were used to calculate volume of the sphenoid sinus (SSV). The SSV were calculated in two ways. First was with computer software using the SPSS data package version17 to evaluate the volume of the SS by using the mean values of the APD, VD, and TD, referred to as MAPD, MVD and MTD respectively by using the formula for simple elliptical volume as: (½×MAPD×MVD×MTD). Another way was by using the formula: V (cm3) = - 2.23 + $[(0.77A–0.018A^2 + 0.00012A^3) r]$. (r= 0.69). This is a formula specific for calculating the SSV with respect to a particular age (A = years), proposed by Yonetsu K et al. The mean of the individual values of the sphenoid sinus volume were obtained for each participant. A pro-forma (see Appendix 3) was used in recording the data before transfer to the computer workstation.

The images obtained from the CT scan was stored in the hard disk of the CT scan workstation at Memfys Hospital, Enugu.

All statistical analysis were conducted using descriptive and inferential statistics under the guidance of a qualified statistician. Descriptive analysis involved the use of tables, cross-tables. Inferential statistics was employed in testing the hypothesis by comparing the mean of the dimensions using the Student’s t-test. The mean, median, and standard deviation (SD) of each dimension will be computed of the Right and left SS, and gender differences analyzed. The association between continuous variables (age and corresponding mean SSD) were investigated by means of Pearson’s correlation coefficient. A probability (p) test of less than 0.05 was used to ascertain the statistical significance of the results. Data analysis were performed with Statistical Package for Social Sciences (version 17 SPSS Inc., Chicago, IL).

All patients had scanned using a CT scan ($Ceretom^R$ portable 8-slice head and neck CT scan machine, model number NL 3000, software WS 01.02) in this study. The participants’ parents or caregivers was specifically consented to the study and clearly informed about the radiation risk.

The data collection and analysis for this research was completed within six (6) months of its approval.

IV. RESULTS

The study consisted of one hundred and four randomly selected asymptomatic male and females between the ages of thirteen and eighteen years whose parents or caregivers consented to the study. There were fifty-two males and fifty-two females recruited into the study. The mean age for male and females were 15.90 and 16.21 respectively, with average mean age for both gender being 16.08 years. Eliminating gender bias, the right MSSD was revealed to be 19.06 mm in the APD, 16.57 mm in the TD and 17.04 mmin the VD. The SSV_A and the SSV_C are 5.09 mm3 and 28.49 mm3 respectively on the right side. While the left MSSD was likewise shown to be 19.81 mm for APD, 16.82 mm for TD and 16.73 mm for VD. The left SSV_A was noted to be 5.04 mm3 while the corresponding SSV_C was 30.16 mm3.

Table 1.1 shows an overview of the descriptive and inferencial Statistics on Sphenoid Sinus dimension (SSD) in the in the black adolescents as demonstrated in the tables

Table 1.1: Descriptive Statistics on Sphenoid Sinus dimension in Adolescent patients

			Anterior posterior		Transverse		Vertical		SSV_A		SSV_C	
Gender	**Statistics**	**Age**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**
	Mean	15.90	19.22	18.84	16.51	15.76	16.50	15.68	5.06	5.02	28.30	25.60
	Median	16.00	19.35	18.70	16.15	16.10	15.90	15.50	5.20	5.20	24.85	20.30
	Minimum	13.00	10.25	7.35	9.25	7.75	7.90	7.20	4.56	3.52	7.82	4.34
	Maximum	18.00	31.10	30.45	30.65	30.10	30.60	30.30	5.32	5.32	117.00	108.00
	Stand. Dev	1.94	4.87	5.64	4.61	4.60	4.42	4.64	0.29	0.38	19.58	19.09
Male	Stand. Error	0.27	0.67	0.78	0.64	0.64	0.61	0.64	0.04	0.05	2.72	2.65

	Mean	16.21	18.91	20.78	16.63	17.88	17.59	17.79	5.12	5.06	28.69	34.71
	Median	17.00	18.38	21.10	16.38	16.30	17.35	17.50	5.25	5.25	25.55	28.80
	Minimum	13.00	7.55	5.35	6.65	9.10	8.50	8.00	4.56	1.80	4.03	1.94
	Maximum	18.00	34.15	32.65	26.90	37.10	29.20	28.00	5.32	5.32	64.90	86.10
	Stand. Dev	1.63	5.53	6.19	4.28	5.49	4.35	4.17	0.23	0.51	14.61	20.44
Female	Stand. Error	0.23	0.77	0.86	0.59	0.76	0.60	0.58	0.03	0.07	2.03	2.83
	Mean	16.08	19.06	19.81	16.57	16.82	17.04	16.73	5.09	5.04	28.49	30.16
	Median	17.00	18.83	19.60	16.38	16.13	16.25	16.65	5.25	5.23	25.30	24.15
	Minimum	13.00	7.55	5.35	6.65	7.75	7.90	7.20	4.56	1.80	4.03	1.94
	Maximum	18.00	34.15	32.65	30.65	37.10	30.60	30.30	5.32	5.32	117.00	108.00
	Stand. Dev	1.79	5.19	5.98	4.43	5.15	4.40	4.52	0.26	0.45	17.19	20.20
Total	Stand. Error	0.18	0.51	0.59	0.43	0.50	0.43	0.44	0.03	0.04	1.69	1.98

Table 1.2: Mean value of Sphenoid Sinus Dimensions (SSDs) in Adolescents (13 to 18 years)

AGE	Statistics	APD_{AVR}	TD_{AVR}	VD_{AVR}	V_{CR}	V_{AR}	APD_{AVL}	TD_{AVL}	VD_{AVL}	V_{CL}	V_{AL}
13.0-13.9	Mean	18.1269	15.7904	14.7846	22.7354	4.5600	18.5346	16.8577	14.8077	23.6615	4.6131
	N	13	13	13	13	13	13	13	13	13	13
	Std. Dev	4.39340	4.41467	3.89762	14.5200	.00000	4.28132	3.58759	3.70843	13.45843	.19137
14.0-14.9	Mean	18.5167	15.7083	16.5000	24.5625	4.8000	18.1833	14.9708	18.6250	26.9708	4.5500
	N	12	12	12	12	12	12	12	12	12	12
	Std. Dev	4.65712	3.51774	1.48752	9.13323	.00000	5.34506	3.63146	3.66262	12.01764	.86603
15.0-15.9	Mean	20.2033	16.9100	18.7000	34.4373	4.9900	19.5700	17.7267	16.8667	31.9293	4.9900
	N	15	15	15	15	15	15	15	15	15	15
	Std. Dev	5.46448	5.27952	4.97092	25.9048	.00000	5.89772	5.87829	5.83875	27.07603	.00000
16.0-16.9	Mean	19.1550	18.1800	19.0400	34.1600	5.2000	21.9900	17.8100	19.2500	38.4400	5.2000
	N	10	10	10	10	10	10	10	10	10	10
	Std. Dev	6.00400	4.08216	4.24557	17.1199	.00000	5.25530	3.90355	3.67340	16.74098	.00000
17.0-17.9	Mean	18.4886	16.0318	17.5955	26.5773	5.2500	21.6173	16.5773	17.3227	31.4918	5.2509
	N	22	22	22	22	22	22	22	22	22	22
	Std. Dev	3.63174	3.25652	4.16796	11.0431	.00000	5.35492	4.66159	3.10942	16.95787	.01875
18.0	Mean	19.4734	16.9063	16.3875	29.0659	5.3156	19.1312	16.9344	15.5562	29.6600	5.2294
	N	32	32	32	32	32	32	32	32	32	32
	Std. Dev	6.30714	5.17381	4.89798	18.7069	.01722	7.22605	6.44957	5.02702	24.09987	.37350
Total	Mean	19.0611	16.5666	17.0442	28.4931	5.0897	19.8113	16.8212	16.7346	30.1589	5.0412
	N	104	104	104	104	104	104	104	104	104	104
	Std. Dev	5.18591	4.42540	4.40066	17.1934	.26316	5.97609	5.14937	4.52015	20.20348	.44821

*** = Significant p value**

Table 1.3: Paired Samples Correlations of Right and Left of Sphenoid Sinus Dimensions (SSDs) in Adolescents (13 to 18 years)

SSD		N	Correlation	P value
Pair 1	APD_{AVR}& APD_{AVL}	104	.390	.000*
Pair 2	TD_{AVR}& TD_{AVL}	104	.188	.056
Pair 3	VD_{AVR}& VD_{AVL}	104	.630	.000*
Pair 4	V_{CR}& V_{CL}	104	.490	.000*
Pair 5	V_{AR}& V_{AL}	104	.580	.000*

*** = Significant p value**

Table 4.4 reveals that there is significant correlation between right and left SSD dimensions exception of TD_{AVR} and TD_{AVL}. The correlation between TD_{AVR} and TD_{AVL} is positive but weak.

Table 1.4: Paired Comparison of Right and Left Sphenoid Sinus Dimensions (SSDs) in Adolescents (13 to 18 years)

SSD		Mean	N	Std. Deviation	Std. Error Mean	P value
Pair 1	APDAVR	19.0611	104	5.18591	.50852	0.220
	APDAVL	19.8113	104	5.97609	.58600	
Pair 2	TDAVR	16.5666	104	4.42540	.43395	0.673
	TDAVL	16.8212	104	5.14937	.50494	
Pair 3	VDAVR	17.0442	104	4.40066	.43152	0.413
	VDAVL	16.7346	104	4.52015	.44324	
Pair 4	VCR	28.4931	104	17.19347	1.68596	0.375
	VCL	30.1589	104	20.20348	1.98111	
Pair 5	VAR	5.0897	104	.26316	.02581	0.178
	VAL	5.0412	104	.44821	.04395	

By the paired t test analysis carried out on the right and left SSD dimensions, it could be inferred that there is significant difference on the sides of SSD dimensions.

Table 1.5: Comparing the mean values of SSDs in male to those in female adolescents (13 to 18 years)

SSD	GENDER	N	Mean	Std. Deviation	Std. Error Mean	P value
APD_{AVR}	M	52	19.2154	4.86503	.67466	0.763
	F	52	18.9067	5.53151	.76708	
TD_{AVR}	M	52	16.5067	4.61171	.63953	0.891
	F	52	16.6264	4.27518	.59286	
VD_{AVR}	M	52	16.4962	4.42134	.61313	0.206
	F	52	17.5923	4.35322	.60368	
APD_{AVL}	M	52	18.8404	5.64222	.78243	0.098
	F	52	20.7823	6.19439	.85901	
TD_{AVL}	M	52	15.7587	4.59972	.63787	0.035*
	F	52	17.8837	5.48567	.76072	
VD_{AVL}	M	52	15.6769	4.64486	.64413	0.016*
	F	52	17.7923	4.17231	.57860	
V_{AR}	M	52	5.0621	0.29295	.04063	0.287
	F	52	5.1173	0.22912	.03177	
V_{AL}	M	52	5.0237	0.37752	.05235	0.693
	F	52	5.0587	0.51242	.07106	
V_{CR}	M	52	28.2969	19.58283	2.71565	0.908
	F	52	28.6892	14.61032	2.02609	
V_{CL}	M	52	25.6040	19.09103	2.64745	0.021*
	F	52	34.7138	20.43500	2.83382	

*** = Significant p value**

In comparing the means of SSDs dimension by the patient gender, it is revealed through independent t test that TD_{AVL}, VD_{AVL} and V_{CL} are significantly different between genders.

V. DISCUSSION

The role of age in the dimension of SS has been recognized in many literatures[3, 9,12,14,22]. This has been linked with the effect of pneumatization on the dimension of the SS. Thus pneumatizing effect on the SS finally brings about the developmental change seen in the SS as one advances in age[2]. Though age is an important factor in SSD, several studies have found that the age related SS morphometry is not continues process, thus at a certain age limit the changes recorded in the SSD remains almost the same[22]. In the adult population it has been found that the SSD doesn't vary significantly between one another[9, 22, 24, 26]. This knowledge is important when considering ETT to the sella region as the screening procedures will entail ruling out developmental anomalies rather than screening for adequacy of the SSD. However in reviewing this study attempt was made to find out the MSSD in the adolescent age group and the likely adequacy of the SSD for trans nasal transsphenoidal access to the sella. The concept of adequacy of the SSD is important because it helps the skull base surgeons to avoiding inadvertent injury to the neurovascular structures around the roof of the SS when accessing the sella[9]. The importance of SSD has been shown in many studies as an important factor that guarantees safety during surgical access to the sella region by preoperative screening. In reviewing this study, it was observed that there is progressive increase in the SSD in the adolescents as the age stratification progresses from 13 years to 18 years, though this did not make a significant statistical difference. This is in compliance with previous study done in the adult population by WU HB, et al in the Chinese population. This study revealed that though there is no significant statistical difference in the SSD among the age groups in these adolescents, there was consistently statistical difference in the value of the V_A either on the right or left of the

SS. This is similar to the finding of Yotnesu K, et al. This may imply that there is need for further evaluation of the volume of the SSD in both adult and in adolescents when considering the adequacy f the SSD for trans-nasal, trans-sphenoidal access to the sella and parasella region. It was noted in this study that using paired t test, the left and right SS showed positive correlation though the TD_{AVR} and TD_{AVL} correlation is positive but weak. Similar findings have been made in other works done in the adult SSD [9,16,22]. The explanation to this findings is that the SS septum has variable point of insertion between the anterior and posterior walls of the SS, thus making an unequal division of the SS. This implies that the attempt has to be made to identify preoperatively the point of insertion of the SS septum because this will lead to a safe access to the sella through the SS. This is because SS septum has been noted as a major guide in avoiding neurovascular injury during exposure of the sellar tursica on the roof of the SS. By following its superior attachment to the roof of the SS gives surgeon early guide in identifying the vital structures [16,19,22,23,26]. One of the challenges that may affect surgeons during access to the sella is the side of the sinus to be used first as a conduit to the sella. In the adult black, Idowu OE, et al, considered this in their study and noted left side bias in the SSD. Similarly, in this work the left SSD was noted to be relatively larger than the right SSD. In like manner, the volume of the SSD (V_C) obtained from the measured dimensions (APD, VD and TD) was shown to be higher than that obtained from the age dependent SSV (V_A). This may imply that even when mathematical formula is used to calculate the age dependent V_A, attempt should be made to radiologically ascertain the dimension of the SS. This is importance especially when selecting instruments for ETT and or microsurgical access to the sella. Anther important factor that affect the SSD is gender. This may arise from the fact that the differential growth pattern especially seen in the adolescent stage between the two genders may influence the overall morphometric changes in the SS. At puberty there is physiological growth sprout in favour of the female sex. This growth pattern is expected to affect all the structures in the body including the SS, though the mechanism is not within the scope of this discuss. However at puberty, the cavity of the SS is said to be already established[11, 12]. This implies that the growth sprout in females may encourage a larger SSD with female bias. This may be the reason for the observation in this study. This information may be a useful guide when considering approach to the sella in these adolescents.

The study of the SSD in the adolescents in this environment showed no significant difference from the already established SSD obtained in the adult from work of Idowu OE, et all. In as much as the raw data obtained in the adult was relatively higher in value than those obtained from the adolescent, it is important to note that the difference made no statistical significance. The implication of this is that surgical procedures to the sella region that are done in the adult through the SS can also be benefited by the adolescents, more so that the SS has been described as a safer corridor to the sella /parasella regions. One of the importance of this study and this observation is that in the adolescents who have sella lesions it is expected that they adequacy of their SS will enable them to benefit from SS corridor. However, in order to maximally benefit from this study, they are expected to be screened using neuroimaging modalities like CT scan, MRI and X-ray.

It is important to ascertain the most efficient modality for screening the sellar region the adolescents. This is because these adolescents have important structures adjacent the sella region that must be secured during any sella procedures through the SS. Among the modalities above, CT scan has been more widely used. This is because of it higher bone penetration than the MRI and X-ray radiography. The use of MRI imaging has advantage over CT scan in identifying soft tissue structures around the SS more especially the neurovascular bundles on the roof and the sidewalls of the sinus. Its low risk of radiation complications makes it the best modality for reviewing the adolescent's SSD that are more prone to radiation induced lesion but for its low sensitivity in delineating the SS pneumatization [29]. However CT scan is better and safer than X-ray radiography in the study of the SSD because of the better image quality that could be generated from the three dimensional (3D) reconstructed images from the former and the higher dose of radiation encountered in the later. Nevertheless, it has been noted that one of the ways of reducing radiation rick in the CT scan images is to reduce the slide number and the body exposure time to the radiation[30]. Thus this study was performed with CT scan in order to improve the sensitivity of the measurements and by using a Ceretom 8 slides CT scan machine, the radiation dose was expected to reduce.

There are some limitations encountered in this study. The measurement accuracy will be better if a higher slide CT scan machine was used like 64 slide machine rather than the 8 slide CT scan machine used in this study. Though the lower slide machine used here helped to reduce radiation risk. The differential body growth rate in the adolescents may have also affected the sensitivity of this research finding. Nevertheless this is the only CT scan based study of the SSD in our environment that has assessed the MSSD in the adolescents and as such, may be a good baseline for further study of the SSD in the adolescents in our environment.

Although this study is give a baseline normal reference range of the of MSSD and the adequacy of the SSD for access to the sella in the adolescents, it is expected that further studies be done to validate it sensitivity and predictive value using a bigger sample size among symptomatic patients. Further clinical collaboration through research will be needed to compare the SSD obtained from these asymptomatic adolescents with those obtained from the symptomatic adolescent group. This will help to fin-tune the usefulness of this measurement for screening, diagnoses and prompt surgical decision for adolescent patients with sella lesion. Extension of this study to the rural population could also help to determine if the gender variation obtained in this study is applicable to a wider population of adolescents.

VI. CONCLUSION

This study has shown that in the adolescent black in the southeastern part or the country has adequate SS morphometry which confers an adequate dimension. The APD was noted to be wider than the other dimensions. The study revealed that the dimension of the SS in the adolescents has female bias with the left sinus having wider dimension. The study shows that CT scan screening of the adolescent's SS will be a useful neuroimaging modality in accessing the SSD for trans-sphenoidal procedures. Further clinically correlated studies from multi institutional collaboration will help to refine the MSSD into a more reliable tool for the screening and advice of surgeons for better sella access in order to avoid iatrogenic intraoperative surgical morbidity.

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