Original Research Paper

Volume - 11 | Issue - 01 | January - 2021 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Radiology

EVALUATION OF VARIATIONS IN SPHENOID SINUS PNEUMATIZATION USING MULTIDETECTOR COMPUTED TOMOGRAPHY IN PATIENTS ATTENDING TERTIARY CARE HOSPITAL, VISAKHAPATNAM

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ABSTRACT **BACKGROUND:** The purpose of our study was to assess the prevalence of different patterns of pneumatization in the sphenoid sinuses as detected on the computed tomography (CT) images of paranasal sinuses of the patients presenting with various pathologies. **MATERIALS AND METHODS:** This is a retrospective radiological study of CT images of paranasal sinuses, done at Radio diagnosis department of a Tertiary care hospital. The study comprised CT images of 500 patients in the age range of 18-75years who were referred for CT scan of paranasal sinuses for various pathologies between the period of July 2018 and July 2019. All images of paranasal sinuses had been acquired following a standardized protocol in axial plane. Their reconstructed images in axial, coronal and sagittal planes were evaluated, using Osirix software, for the extent and different patterns of sphenoid sinus pneumatization. The Images of sphenoid sinuses were assessed for the posterior, lateral and anterior extension of their pneumatization **RESULTS:** The sphenoid sinuses pneumatization patterns in the descending order of prevalence were complete sellar (75.0%), incomplete sellar (22.6%), presellar (2.4%) and conchal (0%). The clival extensions was seen in 75% of patients and lateral extension sides in 49.1% patients. Lateral recesses as assessed on coronal images was seen in 49.1 % of cases with the prevalence in descending order being extension into pterygoid process 59.8 %, greater wing of sphenoid 9.2 %, full lateral 41% and lesser wing (anterior clinoid process) 19.3%. The pure forms were relatively less common and combined forms being more common. **CONCLUSION:** A preoperative review of the sphenoid anatomy should allow for safer endoscopic management of skull base pathology. Radiologists need to be aware of these variations and include them in routine reporting templates

KEYWORDS : Anatomic Variation, Cerebrospinal Fluid Leak, Idiopathic Intracranial Hypertension, Pituitary Tumors, Sphenoid Sinus, Transnasal Endoscopic Surgery

INTRODUCTION

The sphenoid sinus is located in the sphenoid bone in the central skull base. It develops in fourth month of intrauterine life and contains only red marrow at birth. Pneumatization of the sinus begins by nine months of age, and attains its adult configuration by fourteen years of age [1]. Absence of pneumatization is rare and raises the suspicion for existence of conditions that require a large marrow demand to compensate for chronic anemia for example thalassemia and chronic renal failure. Pneumatization progresses in inferior postero-lateral direction and does not extend past the sphenooccipital synchondrosis. Sphenoid sinus by virtue of its central location in the skull base, is not only least accessible but also very crucial to skull base surgery. It is in close proximity to vital structures like the optic, vidian, maxillary, oculomotor, trochlear, and abducent nerves, the cavernous sinuses, internal carotid arteries, pituitary gland, basifrontal lobes and ventral surface of the brain stem. Its lateral and posterior or superior walls are in close contact with Cerebrospinal fluid (CSF) [2]. Transsphenoid access for skull base surgery is fast becoming the most favored approach for the lesions in sella, like pituitary adenomas, optic nerve lesions and various skull base lesions. Sphenoid sinus is very inconsistent in appearance and showing great variations in the degree of pneumatization ranging from minimum to extensive. The pneumatization can extend into the greater wing of sphenoid, pterygoid process, clivus, and into the anterior clinoid process. Variations in pneumatization patterns have a critical impact on surgical planning of the sellar and skull base lesions [3-5]. The detailed data from CT scans of enable the surgeon to interpret any anatomic variations and pathological conditions before initiation of the surgical therapy. In the Hamberger classification [6], the sellar group was classified into conchal, presellar, and sellar type based on their posterior extent with respect to the anterior and posterior walls of sella. Sellar type was further subdivided into incomplete and complete sellar. They were grouped into clival which comprised of subdorsal, dorsal, occipital and combined based on their patterns of extension into the clivus. Lateral recesses comprised of pneumatization extending into the pterygoid processes, greater and lesser wing of sphenoid. Anterior extension comprised of pneumatizaton extending anterior to the sphenoethmoidal recess. The study of sellar extension is important for transsphenoidal approach focused on sellar region. The assessment of extension into as the endoscopic transsphenoid approach extended adjoining areas like the planum sphenoidale, suprasellar region is vital to prevent major endoscopic complications like CSF leak. The knowledge of diverse pneumatization patterns of sphenoid sinus is very important in the era of rapidly evolving transsphenoidal endoscopic surgical intervention for sellar and skull base lesions. These may require tailored approach for each patient as varying extension patterns alter the anatomic relation of the SS with optic nerve, cavernous sinus, internal carotid artery, cranial nerves III-VI, pituitary gland and brain. Lack of knowledge of the pneumatization pattern may inadvertently put these vital structures at risk. Computed Tomography scan of paranasal sinuses with reconstructed images is considered as the basic investigation for evaluation of extended sphenoid sinus pneumatization through the surrounding bones [7-10].

MATERALS AND METHODS

Study participants

It is a retrospective study of CT images of paranasal sinuses of 500 patients presented with various pathologies. The study age group ranges from 18-75years who were referred to Department of Radio diagnosis for CT scan between the period of July 2018 to July 2019. Patients with extensive rhinosinositis, facial trauma, history of paranasal sinus surgery, disease or tumors involving the sphenoid sinus with altered normal anatomical landmarks or patients less than 16 years of age excluded from the study.

The reformatted images were assessed in coronal and sagittal planes to study the prevalence of different pneumatization patterns of sphenoid sinus extension into the pterygoid plates, greater wing of sphenoid, anterior clinoid process, the extent of pneumatization with respect to sellar was classified as pre, incomplete or complete sellar and their clival extention which was grouped as subdorsal, dorsal and occipital.

Classification of types of pneumatization of sphenoid sinus pneumatization:

The sphenoid sinus may show varying degree and directions of pneumatization. These variations alter its normal anatomic relation to

vital structures in the skull base like the optic nerve, cavernous sinus, internal carotid artery, basifrontal lobes, ventral surface of brainstem, cranial nerves III to V, and the pituitary gland, hence exposing them to the danger of being injured during transsphenoidal endoscopic procedures. The prevalence of different pneumatization patterns were assessed by placing in them into various groups based on extent and direction of pneumatization. Posterior extension is seen into sellar and clival region. In the sellar region the pneumatization was grouped into conchal, presellar and sellar type, based on the extension of pneumatization with respect to two lines drawn along anterior and posterior wall of sella turcica on sagittal images. This classification was proposed by Hamberger. Posterior extension of pneumatization into clivus was assessed by grouping them into subdorsal, dorsal, occipital and combined (dorsal and occipital} types based on relation to the posterior wall, the floor of sella and vidian canal. Lateral extensions of pneumatization, was based on extension of the pneumatization beyond the line connecting the medial edge of foramen rotundum and Vidian canal (VR line). It was classified as extension into the greater wing of sphenoid, into the pterygoid process, or both which was named as full lateral. Anterior extension was considered when the anterior wall of the sinus extended beyond the plane of sphenoidal crest and sphenoethmoidal recesses. The lesser wing extension is considered when the pneumatization extended into the anterior clinoid processes. It was also assessed how prevent were the patterns present in combination rather in isolation

Statistical analysis

The compiled data sets were statistically analyzed to determine the prevalence of each type of pneumatization. The quantitative variables were shown in number and percentages. Chi square test was used to compare them. P value >0.05 was considered as insignificant, whereas P value of <0.05 was considered significant and <0.01 was considered highly significant

RESULTS

A total of 500 CT scans of paranasal sinuses of patients in the age group of 17-75 years, with mean of were assessed (Figure 1). Female comprised 42% (210) and males comprised 58% (290) of the study population. There was no statistically significant difference in prevalence of pneumatization patterns between male and females.

From the Table 1 it was found that, there were no cases showing conchal type of pneumatization (0%). Most common pattern was complete sellar seen in 375 (75%) of patients, followed by presellar in 113 (22.6%) and incomplete sellar type in 12 (2.4%) of patients.

Table 2 showed the pneumatization extension cases. Out of 500 CT scans, the clival extension was seen in 375 (75%) of the sinuses. Among 1000 sides examined, most of them were on lateral extension sides (49.1%) and few were in anterior clinoid and Sphenoethmoidal recess sides (19.3%).

Out of 375 clival pneumatization extension cases, most common pattern was subdorsal seen in 261 patients (69.6%) and least were seen in occipital and combined forms (9.9%) (Table 3).

From the Table 4 it was found that, the lateral extension was found in 491 sides (49.1%) of the 1000 sinus walls. Most common lateral extension type was pterygoid extension seen in 294 (59.8 %). It was followed by full lateral extension in 152 (31 %) and greater wing of sphenoid extension seen in 45 (9.2 %) being the least common lateral type. There was a statistically significant difference (P < 0.01) between the lateral extension to the left and right side. The left lateral extensions was more common than the right. The extension into the lesser wing of sphenoid was seen in the form of pneumatization of the anterior clinoid process. It was seen in 193 (19.3%). The optic canal was surrounded by the sphenoid air cells in lesser wing of pneumatization. The Sphenoethmoidal recess sides was found in 193 (19.3%) of the 1000 sinuses (Table 2).

The pure subtypes of pneumatization were seen in 216 sides (21.6%) and the combined forms in 528 sides (52.8%). The common form was isolated Clival extension was seen in 20%, followed by pure lateral in 5.5%, isolated anterior recess was seen in 2.7% with isolated lesser wing extension being least common seen in 1 % cases (Table 5).

Table 1: Prevalence of types of sphenoid sinus pneumatization (500 CT scans)

Type	Number of individuals	Percentages %
Conchal	0	0
Complete sellar	375	75
Presellar	113	22.6
Incomplete sellar	12	2.4

Table 2: Extensions of sphenoid pneumatization on CT (500 patients and 1000 sides)

Pneumatization extension	Number of sides	Percentage %
Clival extension patients	375	75
Lateral extension sides	491	49.1
Anterior clinoid/optic strut (Sides)	193	19.3
Sphenoethmoidal recess sides	193	19.3

Table 3: Clival Extension of sphenoid pneumatization on CT (500 patients and 1000 sides)

Clival extension	Number of sides	Percentages %
Subdorsal	261/375	69.6
Dorsal	40/375	10.6
Occipital	37/375	9.9
Combined (dorsal +Occipital)	37/375	9.9

Table 4: Lateral extension of sphenoid pneumatization on CT (500 patients and 1000 sides)

Lateral extension	Number of sides	Percentages %
Pterygoid	294/491	59.8
Full lateral	152/491	31
Greater wing of sphenoid	45/491	9.2

Table 5: Combined forms of sphenoid pneumatization

Types of combined	Number	Percentage %
clival+ lateral	214	40.6
clival+ lateral + lesser wing	109	20.7
clival+ lateral+ anterior	87	16.4
clival+ lateral+ anterior + lesser wing	34	6.4
clival+ anterior	27	5.1
clival+ lesser wing	19	3.6
lateral+ lesser wing	18	3.4
clival+ lesser wing+ anterior	9	1.7
lateral+ anterior	6	1.1
Lateral + lesser wing + anterior	3	0.6
lateral+ anterior	1	0.2
Lesser wing +anterior	1	0.2

DISCUSSION

The present study evaluates the prevalence of different patterns of extension of sphenoid sinus pneumatization into adjacent bones. The sex of the patient had no relation to the pattern of sphenoid sinus pneumatization. There was significant prevalence of clival and lateral extension of sphenoid sinus pneumatization. The prevalence of combined forms is more common than pure or isolated form. The pre-operative information of these extensions are vital to prevent CSF leakage. The study of extent of pneumatization of the sphenoid sinus has clinical and surgical implications in sellar and central skull base lesions. Based on the available literature [11] from the Caucasian and East Asian populations, it was found that the overall prevalence of conchal type was 1 to 2% where as in the present study there was no conchal type of sphenoid sinus.

According to the study conducted by the Hiremath et al. (2018) [12] highest percentage 76.6% was seen in complete sellar type in sphenoid sinus patients and the results were in agreement to the present study 75%.

The extensions of pneumatization subtypes in the present study population were more in clival type 75%. The pure subtypes of pneumatization were seen at the rate of 21.6% and the combined forms in 52.8%. The common form was isolated Clival extension was seen in 20%, followed by pure lateral in 5.5%, isolated anterior recess was seen in 2.7% with isolated lesser wing extension being least common seen in 1 % cases. These findings were similar to the results of Hiremath et al. (2018) [12] found that pure forms were seen in 25.4% and combined forms in 61% of sinuses. The presellar type (1.2%) was less common and sellar type (98.8%) being common in our population

compared to the Caucasian and East Asian population. The sphenoid sinuses were extensively pneumatized in our population compared to the Chinese and Caucasian population, the prevalence being 76.6%, 68%, and 44.5% for clival; 59.7%, 46%, and 28.3% for lateral recess; 20.4%, 32%, and 12% for lesser wing extension, respectively. The pure forms were relatively less common and combined forms being more common compared to the Chinese and Caucasian population in their study.

Figure 1: Computed tomography images of various sphenoid pneumatizations

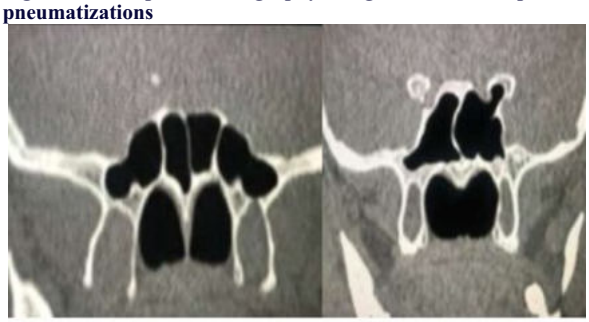

Figure 1a: Pterygoid pneumatization extending inferior to the vidian canal into the pterygoid process

Figure 1b: Lesser wing '' pneumatization extending into the anterior clinoid process

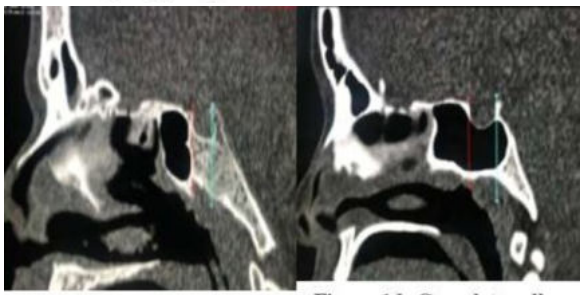

Figure 1c: Presellar type : the posterior margin of pneumatization anterior to the anterior wall.

Figure 1d: Complete sellar : posterior margin of pneumatizationis posterior to the posterior wall of sella

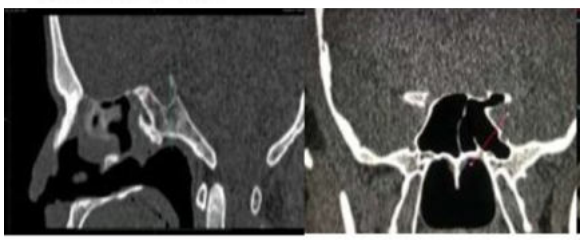

Figure 1e: Conchal type : pneumatization > 10mm anterior to the anterior wall of sella

Figure 1f: Extension of pneumatization into greater and lesser wing of sphenoid

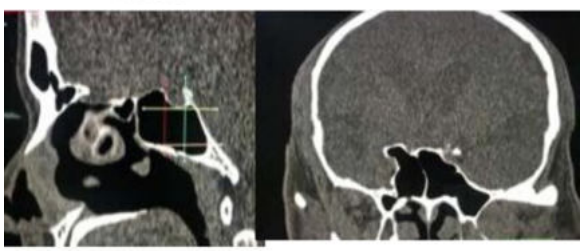

Figure 1g: Occipital type :pneumatization extend inferior to the level of vidian canalabove ineior margin of sella or

Figure 1h: Full lateral pterygoid+greater wing of sphenoid on left side

Endonasal transsphenoidal endoscopy has provided a safe and minimally invasive alternative to cranoiotomy for entire middle compartment of the skull base. The varying patterns of pneumatization of sphenoid sinus alters its normal configuration as well as its anatomic relation with adjacent vital structures. It is imperative to assess the variations to avoid injury to the structures and prevent post-intervention complications like CSF leak, hormonal dysfunction, permanent or transient neurological deficit and visual disturbances. Therefore tanssphenoidal endoscopy requires tailored approach based on individual variations in skull base anatomy. The transphenoid approach to sella and its adjacent skull base structure has undergone numerous advances in technique to include wider area beyond sellar region, including the brainstem. Although hyper pneumatization of Sphenoid sinus allows extended approaches of transsphenoidal surgeries, but it may alter their anatomic configuration and relation with adjacent brain and neurovascular structures, thus putting them at risk during interventions [13-19]. The study was done adopting the classification based on studies by Hamberger et al. (2000) [6] and Wang et al. (2010) [20]. Hamberger et al. divided the sphenoid into sphenoid body type, wherein the pneumatization was restricted to the sphenoid bone and sellar extension was divided into conchal, presellar and sellar type. It is useful to predict the surgical corridor for transsphenoidal surgeries in sellar region and to decide the accessibility of the sella floor during endoscopic surgeries. Sellar type was further subdivided into incomplete and complete types based on the extension of the pneumatizaton beyond the posterior wall of the sella. The Conchal non-pneumatized sphenoid is considered to be a contraindication for extended trans-sphenoidal approach. With advent of newer techniques extended transsphenoidal endoscopic approach was used to access areas beyond the sellar region to include areas bordering the sphenoid sinus like the planum sphenoidale, cavernous sinus, suprasellar region, middle cranial fossa, clival and retroclival region and foramen magnum. However, CSF leakage was higher with extended transsphenoidal approaches compared with standard transsphenoidal approaches as they involved larger bone and dural openings and also penetrating the posterior wall of the sphenoid sinus or breach of anterior cranial fossa during surgery may also result in CSF leakage. Wang et al. (2010) [20] further expanded the classification to include extended pneumatization to lateral, posterior, anterior, lesser wing and combined types. Lateral type where the sinus extends lateral to a line connecting the medial edges of the vidian canal and foramen rotundum (VR line). The lateral extension comprises of pterygoid type, pneumatization extending into pterygoid process only, greater wing type, pneumatization extending into the greater wing of sphenoid only or full lateral type, extending into both pterygoid process as well as greater wing of sphenoid. The left lateral extension is more common than right. Pre-operative identification of lateral type is very vital to avoid injury to the carotid artery, maxillary nerve and vidian nerve, which could lead to extensive hemorrhage or vidian or maxillary neuralgia if inadvertently damaged during intervention..These extensions also increase susceptibility to bony erosion and spontaneous CSF leaks in idiopathic intracranial hypertension and extension of sellar and parasellar lesions into sphenoid sinus. According to Wang et al. (2010) [20] if lateral extensions extends beyond the foramen ovale and foramen rotundum, the middle cranial fossa, which lies lateral to the cavernous sinus, gets exposed after removal of the lateral wall of the sphenoid sinus. The greater wing type of pneumatization facilitates entry route for middle cranial fossa and avoids injury to the mandibular nerve. Clival extension is the posterior extension of pneumatization beyond the posterior wall of the pituitary fossa. Clival extension consists of dorsal, subdorsal, occipital and combined type. They are identified by drawing two horizontal lines at the inferior margin of sella and along the vidian canal and a vertical line along the posterior wall of sella. In Subdorsal type the pneumatization does not extend above the inferior margin of sella or below the level of the vidian canal. In dorsal type, the pneumatization extends superiorly into the dorsum sella. In occipital type, the pneumatization extends inferior to the level of the vidian canal. Combined type included both Dorsal & Occipital type. Clival type of sphenoid sinuses are most favourable for transnasal inlet posterior cranial fossa due to thinner cortex as studied by Wag et al. (2010) Extension into occipital bone is infrequent. Anterior recess type of pneumatization is considered when anterior wall of the sinus extends beyond the sphenoid crest. Its recognition is vital as the sphenopalatine foramen and artery are positioned below the anterior recess. Also injury to the anterior wall of the sphenoid sinus can carry risks of optic nerve injury. The lesser wing type extension is seen as pneumatization extend into anterior clinoid processes and optic struts. These can lead to the protrusion and thinning of bony wall of the optic nerve and internal carotid artery, predisposing them to injury during intervention. Acording to Sirikci et

al. (2000) anterior clinoid process pneumatization has significant association with prominence of the overlying optic nerve into the sphenoid sinus. Recognition of ACP pneumatization is very vital during presurgical evaluation of sellar–suprasellar masses and periclinoid aneurysms to avoid post-surgical CSF leaks. Combined type of pneumatization is considered when more than one type of extensions are seen in the same sinus [21]

CONCLUSION

This study evaluates the prevalence of different patterns of extension of sphenoid sinus pneumatization into adjacent bones. The sex of the patient had no relation to the pattern of sphenoid sinus pneumatization. There was significant prevalence of clival and lateral extension of sphenoid sinus pneumatization. The prevalence of combined forms is more common than pure or isolated form. Pre-intervention, assessment of different types of extension of sphenoid sinus pneumatization is vital to avoid injury of the adjacent vital structures and reduce possibility of CSF leakage. Although extensive pneumatization of sphenoid sinus facilitates extended approaches of transsphenoidal endoscopic surgeries, it poses an increased risk of iatrogenic complications such as neurovascular injuries and CSF leaks, the higher propensity of bony erosion, and sinus extension of sellar and parasellar mass lesions. Radiologists need to be aware of these variations and include them in routine reporting templates. Limitation of our study was inclusion of cases with relatively normal appearance of sphenoid sinuses and also the association between the extent of pneumatization with dehiscence and protrusion of adjacent neurovascular into the sphenoid sinus was not included in our study.

Institutional review board statement: This study was reviewed and approved by The Ethics Committee of GITAM Institute of Medical sciences and Research, Tertiary care hospital, GITAM (Deemed to be University), Visakhapatnam.

Conflict-of-interest statement: All authors declare no conflicts-of-interest related to this article.

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