Evaluation of anatomical variants of sphenoid sinus by multidetector computed tomography

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Abstract

Background: Para nasal sinuses are air-filled cavities present in facial bones. Sinusitis is a common medical problem affecting millions of people annually. CT screening of paranasal sinuses has the advantages of showing bony details and good soft tissue outlines. CT is valuable in the identification of variations in pneumatisation of sphenoid sinuses and characterization of sphenoid variations prior to FESS and trans-sphenoidal surgeries.

Materials and Methods: This was a cross-sectional study conducted at Dr. PSIMS & RF, Chinnavutapalli. This study was done on SIEMENS SOMATOM EMOTION 16 slice spiral CT machine. We included a total of 100 patients clinically diagnosed with chronic sinusitis, who were referred for CT scan of PNS in our hospital.

Results: Out of 100 patients, 52 males and 48 females. Most of the patients were in the 20-30 years age group comprising 55% of the study population. Presellar type of pneumatisation found in (83%), Postellar type of pneumatisation (11%). Pneumatisation of pterygoid process (42%), anterior clinoid process (28%), greater wing of sphenoid (22%). Bilateral protrusion of internal carotid artery (19 cases), right side (5 cases) and on left side (3 cases). Protrusion of optic nerve noted in 21 cases, among these 14 bilaterally, (4) right N and (3) left side, maxillary nerve protrusion (16 cases), among these 8 (bilaterally), (5) right and (3) left side, Vidian nerve protrusion (20 cases), among these (8) bilaterally, (7) right and (5) left side.

Conclusion: Computed Tomography plays an important role in visualization of variation in sphenoid sinus and its pneumatisation patterns and has re-emphasized the concept that variations especially in the sphenoid sinus region is the key factor in the causation of accidental damage to vital structures like ICA, Optic nerve, Maxillary nerve and Vidian nerve.

Keywords: Parasatal sinuses, computed tomography, pneumatisation, dehiscence, protrusion

Introduction

Para nasal sinuses are air-filled cavities present in facial bones. Certain sinuses get pneumatised at certain age period. Among the entire sinuses maxillary sinus is the largest one and first sinus to develop. Sinusitis is a common medical problem affecting millions of people annually. First described over 2 decades ago [1], functional endoscopic sinus surgery (FESS) has become the treatment of choice for patients with medically refractory Rhinosinusitis. FESS procedures are now performed more than 200,000 times per year approximately [2], with published success rates of 76%-98% for primary FESS and 65%-78% for revision cases [3]. The sphenoid sinus is one of the most variable of all sinuses. Its relations to vital vascular and nervous elements make its approach a challenge for endoscopic surgeons [4]. These relations include the internal carotid artery, the optic nerve, the pituitary gland, the Vidian nerve and other vascular and nervous elements depending on the size of the sinus [5, 6]. Sphenoid sinus has close relation to the optic nerve, internal carotid artery, pituitary gland & vidian nerve. According to the extent of sinus pneumatization, the bone covering the carotid arteries, optic nerves, maxillary nerves, and vidian nerves can be thin or even absent, making these structures susceptible to iatrogenic injury [7]. There are multiple variations in septation, shape, and dimensions of the sphenoid sinus.
CT screening of paranasal sinuses has the advantages of showing bony details (using wide window settings) and good soft tissue outlines (using narrow window setting). Axial and coronal views may be useful for delineating the anatomical landmarks of the sinonasal cavity, but coronal CT scan provides most of the information required for an endoscopic clearance. Its advantage over axial CT scanning is that it shows progressively deeper structures as they are encountered by the surgeon during the operation (e.g., sphenoid sinus, in an antero-posterior direction) [7,13]. CT is valuable in the identification of variations in pneumatization of sphenoid sinuses and characterization of sphenoid variations prior to FESS and trans-sphenoidal surgeries [6].

Aims and Objectives
To evaluate the anatomical variations of sphenoid sinuses by multidetector computed tomography.

Materials and Methods
This was a cross-sectional study conducted at Dr. PSIMS & RF, Chinnavutapalli. This study was done on SIEMENS SOMATOM EMOTION 16 slice spiral CT machine. We included a total of 100 patients clinically diagnosed with chronic sinusitis, who were referred for CT scan of PNS in our hospital.

Imaging protocol: For coronal studies, patients were put in prone position. Taking the hard palate as reference axis, the plane of section was perpendicular to this structure. Direct scans of 0.6 mm in thickness were made from the anterior walls of the frontal sinuses to the posterior wall of the sphenoid sinus. The exposure settings used were 130 kVp and 80 to 100 mAs for giving less radiation without compromising on image quality.

Results
Out of 100 patients, 52 males and 48 females. Most of the patients were in the 20-30 years age group comprising 55% of the study population. The commonest symptom being headache (64%) followed by nasal obstruction (53%) and nasal discharge (38%). Conchal type of pneumatisation is very rare and, in our study, there is no conchal pneumatization found i.e. it was noted in 0%. In present study sellar type of pneumatisation is more common which is found in 83%. Postellar type of pneumatisation was noted in 11% in present study. Pre sellar type of pneumatisation was noted in 6% of cases in present study. Extension of pneumatisation from sphenoid sinus to adjacent structures occurs. In present study pterygoid process pneumatisation is common and was noted in 42%. Among these 23% noted bilaterally, 12% noted unilaterally on left side and 7% noted unilaterally on right side. Anterior clinoid process pneumatisation seen in 28%. Among these bilateral anterior clinoid process pneumatisation is seen in 17 cases, unilaterally on right side in 8 cases and left side in 5 cases. Greater wing of sphenoid pneumatisation seen in 22 cases (22%). Among these bilateral greater wings of pneumatisation is seen in 14 cases, unilaterally on right side in 5 cases and on left side in 3 cases. Protrusion of internal carotid artery is more common in present study. It is noted in 27 cases (27%). Among these bilateral protrusion of internal carotid artery noted in 19 cases, right side in 5 cases and on left side in 3 cases. Protrusion of optic nerve noted in 21 cases, among these 14 were noted bilaterally, 4 cases noted on right side and 3 cases on left side. Maxillary nerve protrusion noted in 16 cases, among these 8 cases noted bilaterally, 5 cases noted on right side and 3 cases noted on left side. Vidian nerve protrusion noted in 20 cases, among these 8 cases noted bilaterally, 7 noted on right side and 5 noted on left side. Dehiscence is less common, when compared to protrusion. Dehiscence of ICA, optic nerve, maxillary nerve and vidian nerve are observed in present study. Dehiscence of optic nerve noted in 11 cases, among them 4 cases were noted bilaterally, 4 cases on right side and 3 cases on left side. Dehiscence of internal carotid artery is next common in present study. ICA dehiscence is seen in 13 cases, among them 8 were noted bilaterally, 3 on right side and 2 on left side. Dehiscence of maxillary nerve is noted in 8 cases, 3 bilaterally, 3 on right side and 2 on left side. Dehiscence of vidian nerve seen in 16 cases, among them 9 was noted bilaterally, 4 on right side and 3 on left side. Number of septae in sphenoid sinus can be variable, they can be absent septum, single, double or multiple septae in present study sphenoid sinuses with single septum are 72 cases, multiple septae are 19 cases and sphenoid sinus with absent septae are 9 cases.

Discussion
The normal anatomical variations of the sphenoid sinus pneumatisation (TABLE 5) and relations with adjacent structures are implicated in the etiology of accidental damage of vital structures like ICA, Optic nerve, Maxillary nerve & Vidian nerve. In this study Computed tomography images of a group of 100 patients were studied to evaluate anatomical variations of sphenoid sinus and its Pneumatization.

Anatomy
The sphenoid sinus is the most posterior paranasal sinus. It lies antero-inferior to the sella. At birth, sphenoid sinus is a potential cavity, after development during puberty it reaches its original size. At first years of life, it extends backward into the presellar area and gradually expands into the area below and behind the sella turcica, and reaches its full-size during adolescence. During childhood, maturation of the bone from red to yellow marrow takes place in the anterior part of the sphenoid bone. Aoki et al. hypothesized that pneumatization promotes the conversion of the sphenoid marrow). Pneumatization widens inferiorly and postero-laterally and does not exceed the sphenoid-occipital synchondrosis. At 14 years of age, its expansion is completed but pneumatization proceeds slowly and completely ceases by the age of 25. Size and degree of pneumatization of sphenoid sinus is an important concern for the decision of surgery of sellar region. The types of the sphenoid sinus can be classified in three groups in the adult: I. conchal, II. presellar, III. sellar types and Postsellar (FIG 2), depending on the extent to which the sphenoid bone is pneumatized. In the conchal type, the area below the sella is a solid block of bone without an air cavity. In the presellar type (Fig 1), the sphenoid sinus has moderate air cavity with no sellar indentation. The sellar type (Fig 3), which is the most common, the corpus of the sphenoid is well pneumatized with full indentation of the sella into the sinus and extends posteriorly until the clivus. The conchal type is most common in children and infrequent in the adult [13]. The pneumatization pattern of the sphenoid sinus is variable and can extend to
surround the anterior clinoid process (ACP), foramen rotundum, vidian canal, pterygoid process, or the maxillaethmoid process. The relations of the sphenoid sinus with structures around are close when the sinus is well pneumatized. When this happens, the surrounding vessels and nerves are seen in the sinus cavity as irregularities or ridges [14]. The sphenoid sinus may pneumatise the anterior clinoid processes. When present this pneumatization can encroach the optic nerve [15, 16]. The incidence of pneumatization in the anterior clinoid processes in literature is between 11% and 29.3% [17,18]. The pneumatization of the sphenoid to the ptterygoid processes is an extension of the sinus between the maxillary nerve and the nerve of the pterygoid canal (Vidian nerve). The internal carotid artery is the most medial element of the cavernous sinus, and it lies in direct relation to the lateral wall of the sphenoid sinus.

**Sphenoid pneumatization**

In our study, Conchal type of pneumatization is very rare 0%. Sellar type of pneumatization is more common, which was evident even in other studies. In present study sellar type of pneumatization is found in 83%. Post sellar pneumatization is next common variety. Post sellar type of pneumatization was noted in 11% in present study. Presellar type of pneumatization was noted in 6% of cases in present study. The studies done by showed the most common variant as sellar type Budu. et al. sellar 65%, Hamid. O. et al. sellar 54% and Nathan et al. sellar 54%, which coincides with our study results.

**Extension of sphenoid pneumatization**

Extension of pneumatization from sphenoid sinus to adjacent structures occurs. In present study pterygoid process pneumatization was noted in 42% among these 23% noted bilaterally, 12% noted unilaterally on left side (Fig 6) and 7% noted unilaterally on right side (Fig 4). Anterior clinoid process pneumatization is next most common in present study; it is associated with optic nerve protrusion. Anterior clinoid process pneumatization (Fig 7) seen in 28% among this bilateral anterior clinoid process pneumatisation is seen in 17 cases, unilaterally on right side (Fig 4) in 8 cases and left side in 5 cases. Greater wing of sphenoid pneumatization seen in 22 cases (22%) among these bilateral greater wings of pneumatization is seen in 14 cases, unilaterally on right side (Fig 5) in 5 cases and on left side in 3 cases. In a study done by Rudresh et al. extension of pneumatization to Pterygoid process was 31%, to anterior clinoid process was 15% and to Greater wing of sphenoid was 12.7%. In a study done by Hewaidi. et al. extension of pneumatization to Pterygoid process was 29%, anterior Clinioid process was 15.3% and to Greater wing of sphenoid was 20%. In a study done by Budu et al. extension of pneumatization to Pterygoid process was 39%, anterior clinoid process was 29% and greater wing of sphenoid was 0%. This comparison of studies with study results shows greater correlation with the existing studies.

**Protrusion of adjacent vital structures**

Protrusion of internal carotid artery (Table 2) is more common in present study. It is noted in 27 cases (27%). Among these bilateral protrusion of internal carotid artery (Fig 14) noted in 19 cases, right side in 5 cases and on left side in 3 cases. Protrusion of optic nerve (Table 1) noted in 21 cases, among these 14 were noted bilaterally, 4 cases noted on right side and 3 cases on left side. Maxillary nerve protrusion (Table 3) noted in 16 cases, among these 8 cases noted bilaterally (Fig 12), 5 cases noted on right side and 3 cases noted on left side. Vidian nerve protrusion (Table 4) noted in 20 cases, among these 8 cases noted bilaterally (Fig 11), 7 noted on right side and 5 noted on left side. In a study done by Sareen. et al. the protrusion of internal carotid artery was 36%, optic nerve was 30%, maxillary nerve was 19.7% and vidian nerve was 23.1%. This study shows good correlation of results with the existing studies.

### Table 1: Relationship between pneumatization of ACP and on protrusion

| Anterior clinoid process pneumatisation | Optic nerve protrusion (ONP) |  |  |
|---------------------------------------|------------------------------|--|--|
|                                       | Present (ON+) | Not present (ON-) | Total |
| Present (ACP+)                        | 21             | 75               | 28    |
| Not seen (ACP-)                       | 0              | 0                | 100   |
| Total                                 | 21             | 79               | 100   |
Relationship between pneumatisation of ACP and ICA protrusion
Concomitant presence of a pneumatised ACP and a protruding ICA was encountered in 25 cases. Chi square test indicated significant association between ACP pneumatisation and ICA protrusion. ($\chi^2 = 72.2$ with 1 degree of freedom, $p < 0.001$).

Table 2: Relationship between pneumatisation of ACP and ICA protrusion

| Anterior clinoid process pneumatisation | Internal carotid artery protrusion (ICAP) | Total |
|----------------------------------------|------------------------------------------|-------|
|                                        | Present (IC+) % | Not present (IC-) % | Number | % |
| Present (ACP+)                         | 25             | 3               | 28     | 89.2% | 10.8% | 27 |
| Not seen (ACP-)                        | 2              | 70              | 72     | 2.7%  | 97.3% | 73 |

Table 3: Vidian nerve protrusion

| Vidian nerve protrusion | Pterygoid process pneumatisation | Total |
|-------------------------|----------------------------------|-------|
|                         | Present (VNP+) % | Not present (VNP-) % | Number | % |
| Present (PP+)           | 20             | 22               | 42     | 45%  | 55% |
| Not seen (PP-)          | 0              | 58               | 58     | 0%   | 100%|
| Total                   | 20             | 80               | 100    |      |     |

Relationship between GWS pneumatization & maxillary nerve protrusion (MNP)
Concomitant presence of a pneumatized GWS and a protruding maxillary nerve was encountered in 20 cases. Chi square test indicated significant association between GWS pneumatization and MN protrusion. ($\chi^2 = 30.6$ with 1 degree of freedom, $p < 0.001$).

Table 4: Comparison of outcome of various studies on anatomical variations in sphenoid sinus on CT

|          | Present study | Fasunla AJ et al. | Budu et al. | Haid O et al. | Rudresh et al. | Hewaidi GH et al. | Nathan et al. | Sareen D et al. |
|----------|---------------|------------------|-------------|---------------|----------------|-------------------|---------------|-----------------|
| Year     | 2015          | 2012             | 2013        | 2008          | 2010          | 2011             | 2014          | 2008            |
| Sphenoid pneumatisation | | | | | | | | |
| Conchal | 0%            | 02%              | 02%         | 00%           | 00%           | 00%               | 00%           | 00%             |
| Sellar  | 83%           | 65%              | 54%         | 37%           | 40%           | 54%               | 55%           | 55%             |
| Post sellar | 11%        | 23%              | 22%         | 09%           | 09%           | 09%               | 09%           | 09%             |
| Pre sellar | 06%         | 10%              | 21%         | 09%           | 09%           | 09%               | 09%           | 09%             |
| Extension of pneumatisation | | | | | | | | |
| Pterygoid | 42%          | 39%              | 31%         | 29%           | 29%           | 29%               | 29%           | 29%             |
| Ant-clinoid | 28%         | 14.5%            | 29%         | 15%           | 15.3%         | 15.3%             | 15.3%         | 15.3%           |
| Greater wing of sphenoid | 22%          | 15.9%            | 12.7%       | 20%           | 20%           | 20%               | 20%           | 20%             |
| Protrusion | | | | | | | | |
| ICA      | 27%           | 27.3%            | 34%         | 7%            | 41%           | 36%               | 36%           | 36%             |
| ON       | 21%           | 38.2%            | 10%         | 35.7%         | 30%           | 30%               | 30%           | 30%             |
| MN       | 16%           | 12%              | 24.3%       | 19.7%         | 19.7%         | 19.7%             | 19.7%         | 19.7%           |
| VN       | 20%           | 31.2%            | 27%         | 23.1%         | 23.1%         | 23.1%             | 23.1%         | 23.1%           |
| Dehiscence | | | | | | | | |
| ICA      | 13%           | 10.9%            | 04%         | 3%            | 3%            | 3%                | 3%            | 3%              |
| ON       | 11%           | 13.6%            | 5%          | 5%            | 5%            | 5%                | 5%            | 5%              |
| MN       | 08%           | 2.75%            | 13%         | 13%           | 13%           | 13%               | 13%           | 13%             |
| VN       | 16%           | 3.75%            | 37%         | 37%           | 37%           | 37%               | 37%           | 37%             |
| Septum   | Present | 91%              | 97.3%       | 89.2%         | 96%           | 100%              | 96%           | 100%            |
|          | Absent | 09%              | 2.7%        | 10.8%         | 04%           | 00%               | 04%           | 00%             |

Figures

Fig 1: Pre sellar type of pneumatisation
Fig 2: Post sellar pneumatisation

Fig 3: Right anterior clinoid process pneumatisation.
Right pterygoid process pneumatisation.

Fig 4: Greater wing of sphenoid pneumatisation on right side.
Pterygoid process pneumatisation on right side.

Fig 5: Left pterygoid process pneumatisation
Fig 6: Greater wing of sphenoid pneumatisation
Maxillary nerve protrusion
Pterygoid process pneumatisation
Vidian nerve protrusion

Fig 7: Vidian nerve dehiscence
Vidian nerve protrusion

Fig 8: Bilateral vidian nerve protrusion

Fig 9: Bilateral maxillary nerve protrusion

Fig 10: Maxillary nerve protrusion
Maxillary nerve dehiscence
Greater wing of sphenoid pneumatisation
Pterygoid process pneumatisation

Fig 11: Internal carotid artery protrusion

Fig 12: Internal carotid artery dehiscence
ACP pneumatisation

Fig 13: Single septum
Conclusion
This study has demonstrated that Computed Tomography plays an important role in visualization of variation in sphenoid sinus and its pneumatisation patterns and has re-emphasized the concept that variations especially in the sphenoid sinus region is the key factor in the causation of accidental damage to vital structures like ICA, Optic nerve, Maxillary nerve and Vidian nerve. It helps in evaluating the complex anatomy of paranasal sinuses which is not possible with plain radiographs. Improvement in FESS and CT technology has concurrently increased interest in the sphenoid sinus anatomy, pneumatisation and its variations. The radiologist must pay close attention to variants of sphenoid sinus and its pneumatisation patterns in the preoperative evaluation as it is important for the surgeon to be informed of these variations, protrusion/dehiscence of ICA, Optic nerve, Maxillary nerve and Vidian nerve which may predispose patients to increased risk of intra-operative complications/recurrent failures thereby helping avoid possible complications and accidental damage to vital structures.

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