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Original Article

Neurovascular Variations of Sphenoid Sinus: Impact on Transsphenoidal Surgery

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Abstract

Aim: The aim of the study was to analyze the variations of neurovascular structures located in the sphenoid sinus in the form of optic canal (OC), vidian canal (VC), and foramen rotundum (FR), and carotid canal (CC) protrusion. The location of FR and VC from midline in relation to the lateral recess pneumatization (LRP).

Materials and Methods: Computed tomography images, 1mm thin axial sections for 100 patients (50 male and 50 female) over the age of 18 years, obtained for any reason at our hospital were evaluated retrospectively with coronal and sagittal reconstructions. Patients with craniofacial trauma and any pathology (sinonasal malignancy, rhinosinusitis, and nasal polyps) distorting the normal anatomy were excluded. The type of sphenoid sinus in the axial, coronal and sagittal sections, the variations in the form of protrusions, and location from midline as a function of the LRP was analyzed.

Results: The sellar (98%) and greater wing (31%) types were common in sagittal and coronal types. The LRP was not impacted by age. The FR was laterally placed on the left side ($P < 0.001$) when compared with the right. Bilaterally, the mean distance of FR from midline was compared, and the patients with LRP had significantly laterally placed FR (Left and Right - $P < 0.001$). This difference was not present in the VC location (Left-value = 0.205, right $P = 0.266$).The protrusion of the OC was associated with the anterior clinoid process (ACP) pneumatization, FR and VC protrusion with LRP was significantly associated ($P < 0.001$). OC and CC dehiscence was 16% and 3%.

Conclusion: The LRP displaces the FR laterally than the VC. The protrusion of the VC, FR is significantly associated with the LR pneumatization as such as OC and ACP. Thus, the pre-operative analysis of the neurovascular structural variations would bring down the complication rates and help plan for the extended approaches.

Key words: Carotid canal, Dehiscence, Foramen Rotundum, Lateral recess Pneumatization, Optic canal Dehiscence, Optic canal protrusion, Protrusion, Vidian canal.

INTRODUCTION

The sphenoid sinus pneumatization is divided into Presellar, Sellar, and conchal type traditionally. This classification is based on sagittal extent of the pneumatization. Recently, Wang *et al*. have classified the sphenoid sinus based on the pneumatization in the coronal plane into sphenoid body type, greater wing type, and pterygoid type, and full lateral type.

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The neurovascular structures in relation to sphenoid sinus, namely the optic canal (OC), carotid canal (CC), vidian canal (VC), and foramen rotundum (FR), the dehiscence and protrusion are affected by the extent of pneumatization.

The location of the neurovascular structures from the midline also varies. We intended to study these variations in the distance as a function of pneumatization in the lateral recess (LR).

Aim

The aim of the study was to analyze the variations of neurovascular structures located in the sphenoid sinus in the form of OC, VC, and FR, and CC protrusion

The location of FR and VC from midline in relation to the lateral recess pneumatization (LRP).

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MATERIALS AND METHODS

A retrospective cross-sectional study of 100 patients (50 male and 50 female) was done. The patients who underwent CT evaluation for PNS or temporal bones for any reason were included in the study. All the patients were evaluated at Goverment Rajaji Hospital, Madurai, India. 1 mm thin sections were obtained using 16 slices Toshiba scanner. The coronal and sagittal reconstructions made. Measurements were done using Radiant Dicom software.

The patients who had craniofacial fractures, Sinonasal malignancy or polyposis, disruption of the skull base and rhinosinusitis altering the anatomy were excluded.

The type of the sphenoid sinus in the axial, sagittal, and coronal planes was analyzed. The lateral extent of pneumatization was analyzed separately between the right and left side and also between the male and female gender. The impact of age on lateral pneumatization was analyzed as a function of FR and VC distance from the midline.

We divided the patients into two groups. The patients with greater wing, pterygoid, and full lateral type were grouped into one as they corresponded to LRP. The second group of patients had the only sphenoid body type of sinus, i.e. without LRP. The location of the FR and VC from the midline was compared between the left and right side in the two groups.

The protrusion is defined as the bulging of the canal or foramen into the sphenoid sinus exposing 50% or more of the structure, with or without bony wall defects.[5] Dehiscence is defined as the absence of the bony wall in part or full.

The protrusion and dehiscence of the OC, CC, FR, and VC were noted. The association between the OC, FR, VC, and CC protrusions with the lesser wing, greater wing, pterygoid, and full lateral types was analyzed.

Measurements

- Distance from the midline to VC - Right and left side.
- Distance from the midline to FR - Right and left side.
- Distance between the Two FR and VC.
- Direct distance between the FR and VC.

Statistical Analysis

All data were entered into Excel 2007, and statistical analysis was performed using the statistical software SPSS 16.0. Data were expressed as percentages, mean values (with standard deviations). Independent sample *t*-test was used to calculate the difference between means and Pearson's Chi-square test was used for proportions. Pearson's correlation coefficient was used to find the correlation between continuous variables. Results were defined as statistically significant when *P* value (2-sided) was <0.05.

RESULTS

The sellar type of the sphenoid sinus was the most common (98%), and no conchal type was present in the study. The distribution of the sphenoid sinus type is shown in Table 1.

The lateral pneumatization as in the greater wing (31%), pterygoid (33%), and full lateral (27%) types were common in the left side. The lesser wing pneumatization was common in the right side (24%) as shown in Table 2.

There is no correlation between age and lateral pneumatization as shown in Table 3. Figure 2 showing the graphical representation.

The FR on the left side was place laterally when compared with the right side. The mean distance was statistically significant ($P < 0.001$). The mean distance for the VC did not achieve statistical significance when compared between the left and right side ($P = 0.078$) Figure 1.

Table 1: Distribution of the sphenoid types in the axial and sagittal sections in the study

Parameter	Total (%)	Male (%)	Female (%)
Sellar	95	47 (94.0)	48 (96.0)
Presellar	5	3 (6.0)	2 (4.0)
Conchal	0	0	0
Anterior	37	14 (28.0)	23 (46.0)
Dorsal	4	4 (8.0)	0
Sub dorsal	22	14 (28.0)	8 (16.0)
Occipital	36	17 (34.0)	19 (38.0)

Table 2: Distribution of the sphenoid sinus pneumatization in coronal sections. All values are expressed in percentages

Parameter	Right			Left		
Types	Total	Male	Female	Total	Male	Female
Lesser wing	24	26	22	18	9	9
Greater wing	26	12	14	31	17	14
Pterygoid	27	12	15	33	15	18
Full lateral type	23	10	13	27	13	14

Table 3: The correlation between age and the distance of FR and VC from midline

Parameter	Correlation coefficient (r)	*P*
Age versus VC - right	−0.044	0.666
Age versus VC - left	−0.060	0.556
Age versus FR - right	−0.124	0.221
Age versus FR - left	0.021	0.834

VC: Vidian canal, FR: Foramen rotundum

The distance of the FR from the midline was more in the group of patients who had lateral pneumatization than in the sphenoid body type. The p value was significant for both the left ($P < 0.001$) and right side ($P < 0.001$). When analyzed for the VC there was no statistically significant difference between the both groups on either side. Left - $P = 0.205$, right $P = 0.266$ as shown in Table 4.

The OC protrusion was significantly associated with the lesser wing type corresponding to the anterior clinoid process (ACP) pneumatization ($P < 0.001$). The FR, VC, and CC protrusion was significantly associated with the greater wing ($P < 0.001$), pterygoid ($P < 0.001$), and full lateral ($P < 0.001$) types bilaterally.

Figure 1: Full lateral type of pneumatization bilaterally with optic canal, foramen rotundum and vidian canal protrusions

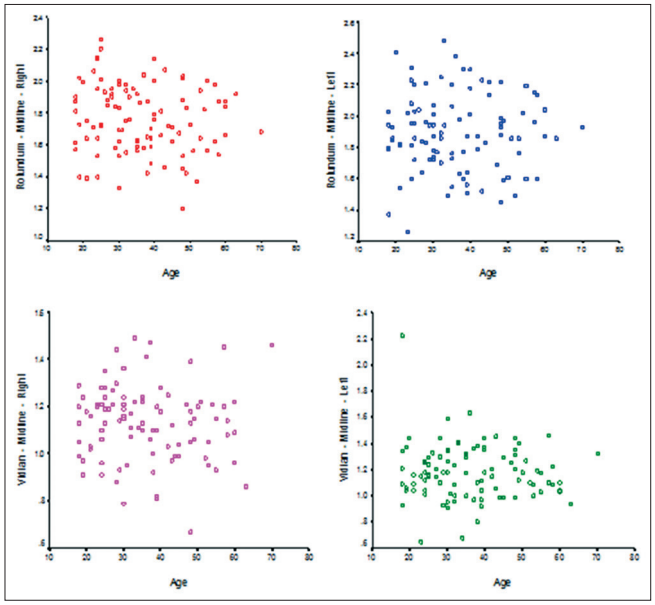

Figure 2: Scatter plot between the age and distance of foramen rotundum (FR) from the midline (top left - age vs. FR on the right side), top right - age versus FR on the left side, bottom - scatter plot between the age and distance of vidian canal (VC) from the midline. (Bottom right - Age vs. VC on Right side, Bottom Left - Age vs. VC on Left side). There was no significant correlation between age and lateral pneumatization

Further, when the association between the FR, VC protrusions, and pneumatization was compared between the sphenoid body and the lateral type groups, they were more significantly associated with the lateral pneumatization group ($P < 0.001$) bilaterally as shown in Table 5.

DISCUSSION

The development of the sphenoid sinus starts mainly after the puberty. The sinus is present mostly at birth as small cavities. The pneumatization proceeds from the presellar area to begin with and expands to the sellar and postsellar areas progressively.[1] This accounts for the classification in the sagittal plane. The pneumatization also expands laterally in the coronal plane. This may extend up to the VC or with the LRP between the VC and the FR.

The pneumatization extent alters the location of neurovascular structures inside the sphenoid sinus. This reminds us of the position of the facial nerve in relation to the pneumatization of the temporal bones.[1] The important structures in relation to the sphenoid sinus are the OC, VC, and FR, and CC protrusion. The location varies in terms of the distance from the midline or the amount of protrusion or dehiscence of the canal.

The transsphenoidal surgeries to approach the sellar, middle cranial fossa, Meckel's cave, posterior ethmoid, or sphenoid sinus *per se* are increasingly used. The variations in the sphenoid sinus are common than being an exception. The anatomical evaluation preoperatively helps to reduce complication rates.

Table 4: The comparison of distance of VC and FR from midline between the sphenoid body and LRP on both sides

Parameter	Right			Left		
	Sphenoid	Lateral	*P*	Sphenoid	Lateral	*P*
VC	1.12±0.2	1.16±0.1	0.266	1.16±0.2	1.22±0.2	0.205
FR	1.69±0.2	1.91±0.2	<0.001	1.82±0.2	2.02±0.2	<0.001

VC: Vidian canal, FR: Foramen rotundum, LRP: Lateral recess pneumatisation

Table 5: *P* values when protrusion was compared between sphenoid and lateral types

Protrusion	Right	Left
OC	0.014	0.072
VC	<0.001	<0.001
FR	<0.001	<0.001
CC	0.092	0.021

VC: Vidian canal, FR: Foramen rotundum, OC: Optic canal, CC: Carotid canal

Optic Nerve Protrusion

The optic nerve protrusion is defined as the bulging of the OC into the sphenoid sinus exposing more than 50% of its circumference, with or without bone defects[5] OC dehiscence is defined as the absence of the bony wall. The OC protrusion and dehiscence increased with sphenoid sinus pneumatization.[4]

In our study, OC protrusion is 16% as with Sirikci *et al.* (31%)[5] and Unal *et al.*[6] The OC dehiscence was in the intermediate range as 15% when compared with Unal *et al.*[6] 8%, Fuji *et al.* (4%), and Hewaidi and Omami (30%)[7] we also observed that the bone separating the canal was thin in patients having OC protrusion.

Optic nerve is divided into four segments. The intracanalicular part is the least nourished. The optic nerve can be injured rendering the patient blind by the surgical procedure or due to the sinus infection after the surgery. The mechanism has proposed to be ischemia or venous congestion.[2,3]

The lesser wing type of pneumatization has the sphenoid sinus pneumatization extending into the ACP thus encircling the OC. We had a significant association in patients with ACP pneumatization having OC protrusion ($P < 0.001$). Thus, as the pneumatization extends, protrusion or dehiscence of the OC increases.

Internal Carotid Artery Protrusion and Dehiscence

The carotid artery protrusion and dehiscence are described in the same way as OC. The CC protrusion exposes more than 50% of the circumference of the artery and dehiscence as the absence of the bone. The carotid artery can be just covered by the sinus mucosa when the bone is dehiscent. The above anatomical variations increase the iatrogenic injury risk. Tackling the bleeding is difficult and would lead to neurological sequelae.

In our study, the CC protrusion was 17% in the right side and 16% in the left side. When compared with other studies having a very wide variation from 67% in Asian cadavers [Tan and On[g][9]] to 26.1% [Sirikci *et al*.[5]] and 30.3% [Unal *et al*.[6]] in Turkish population. The protrusion was more in Asian population.

The CC dehiscence in our study is 3%. It ranged from 1.5% by Kazkayasi *et al.*[10] to 22% in Sirikci *et al.*[5]

FR and VC

In our study, the FR distance from the midline more in the left side when compared with the right. The VC distance between the left and right from the midline did not differ significantly [Table 6].

Table 6: Comparison of distance from midline

Parameter	Right	Left	*P*
	mean±SD (*n*=100)	mean±SD (*n*=100)	
VC	1.13±0.2	1.18±0.2	0.078
FR	1.76±0.2	1.89±0.2	<0.001

VC: Vidian canal, FR: Foramen rotundum, SD: Standard deviation

When the location of the FR was analyzed as a function of the lateral pneumatization, the distance of the FR was significantly placed distant from the midline in all three types of LRP, namely greater wing type, pterygoid type, and full lateral type. The distance on both left and right side achieved significance when analyzed as a function of pneumatization.

In the study by Vaezi *et al.*,[1] in 2015, showed that the distance measured directly between the FR and VC increased as the pneumatization extended laterally. The lateral pneumatization was analyzed as a function of depth and surface area of the LR.

In the study by Kasemsiri *et al.*,[11] the distance from the midline to the left FR was significantly more than the right side. Similar results were obtained by the Mohebbi *et al.*[12]

CONCLUSION

The pneumatization of the sphenoid sinus causes the variations in the location of the neurovascular structures. Pre-operative analysis of the LRP will help in analyzing the location of neurovascular structures and in the planning of surgical procedure to the sphenoid sinus, and its extensions in the transpterygoid and Meckel's cave approaches. The complication rates can be brought down with thorough anatomical knowledge.

Our study has shown that the protrusion is more when the LR is pneumatized for FR, VC, and CC exposing to risk of surgical injury.

Furthermore, when the LR is pneumatized, FR is laterally placed increasing the access to the middle fossa and Meckel's cave.

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