A Radio-Anatomic Profile of the Sphenoid Sinus, Vidian Canal and Foramen Rotundum Structured

Ramanna H.C.[1], Samarth S. Gowda[2], Jithendra N.[3], Vijay Kumar K.R.[4]

[1, 2, 3] Department of Radiodiagnosis, Bangalore Medical College and Research Institute, Bangalore, Karnataka, India. [4]Department of Radiodiagnosis, Bowring and Lady Curzon Hospital, Bangalore, Karnataka, India.

ABSTRACT

BACKGROUND

One of the most vital structures in the anterior skull base surgeries is sphenoid sinus. Sellar, parasellar, suprasellar and clival lesions can be easily accessed using sphenoid sinus and is one of the most variable of all the paranasal sinuses in terms of its surrounding anatomical relationships. It also serves as a natural route for surgical entry to the middle cranial fossa and the cave of Meckel. Further, foramen of Rotundum and the canal of Vidian serve as vital gateways to important neurovascular structures, and their close proximity to the sphenoid sinus makes it necessary for the operating surgeon to have a better understanding of this anatomical 'Holy trinity'. By shedding light on this complex anatomical relationship through the course of our study, we hope to be of better assistance to the operating surgeons.

METHODS

100 consecutive CT scans of the paranasal sinuses performed for any cause, were reviewed retrospectively to look for the sphenoid sinus and its anatomical relationship to the foramen rotundum and vidian canal. All the computed tomography scans were performed using Philips Ingenuity 128 slice CT scanner. 3 mm slice contiguous images were taken, and 1 mm slice reconstruction was performed. Images were reviewed in three orthogonal planes.

RESULTS

Based on the study, the most common type of foramen rotundum was 'Type IIB' and the most common position of foramen rotundum in relation to sphenoid sinus based on lateral pterygoid plate was found to be the 'online' type. The most common variation in the Vidian canal anatomy was found to be the 'Type II' canal. No association was found between types of foramen rotundum and vidian canals with position of foramen rotundum.

CONCLUSIONS

Knowledge of the complex anatomical relationship of sphenoid sinus is important for skull base surgeries. Results of the study help us to understand the most common anatomical variations, thus aiding in better surgical outcomes.

KEYWORDS

Sphenoid Sinus, Lateral Pterygoid Plate, Foramen Rotundum, Vidian Canal

Corresponding Author:
Jithendra N,
#151, First Floor,
5th A Main Road, 14th Cross,
A Sector, Yelahanka New Town,
Bengaluru - 64, Karnataka, India.
E-mail: jithendra.n2402@gmail.com

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BACKGROUND

One of the most vital structures in anterior skull base surgeries is sphenoid sinus (Figure - 1). Sellar, parasellar, suprasellar and clival lesions can be easily assessed using sphenoid sinus. It also serves as a natural route for surgical entry to the middle cranial fossa and the cave of Meckel. Important anatomical structures like cavernous sinus with cranial nerves within, internal carotid arteries and optic nerves are closely associated with sphenoid sinus. Body of pterygoid acts as a surgical window for middle cranial fossa surgeries.[1]

The sphenoid sinus is not pneumatised at birth, pneumatisation usually starts at 6 months, but its development to adult size takes place after attaining puberty. Early in the life, extension of sphenoid sinus takes place posteriorly into the pre-sellar area, as age progresses expansion takes place up to the sella turcica and region which is inferior and posterior to it which corresponds to the adult size. Extension of sphenoid sinus into pterygoid base or greater wing or to the basiocciput of the occipital bone will take place whenever there is enormous pneumatisation. Optic canals with it nerves which lie in close relation to sphenoid sinus may get encircled by enlarged sphenoid sinus. In the well - pneumatized sphenoid sinus, the surrounding neurovascular structures which are contiguous with the sinus will be separated by a thin bony septum or can be even dehiscent in few cases. Hence knowledge of anatomical relationships is of great clinical importance especially in surgical cases.

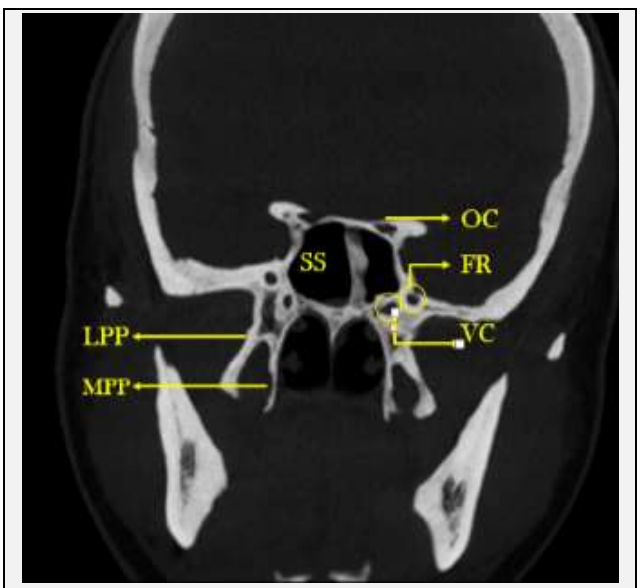

Figure 1. Coronal Reformatted Maximum Intensity Projection Image Showing Sphenoid Sinus

FR- Foramen Rotundum; SS – Sphenoid Sinus; OC – Optic Canal; VC – Vidian Canal; MPP – Medial Pterygoid Plate LPP – Lateral Pterygoid Plate;

In recent years endoscopic surgery has emerged as best surgical modality for skull base surgeries. This development has led to new provocations for gaining better knowledge of sphenoid sinus and its anatomical relationships. As a consequence, new prototypes of anatomical relationships have evolved which acts as a surgical leading light to the skull base surgeon who use endoscopic approach.[2]

Why knowledge of anatomical variations are important?

a. Recent advances in endoscopic surgery has led to wide usage for various skull based surgeries.
b. Variation of sphenoid sinus is more compared to other sinuses.
c. Approach to this sinus is difficult for endoscopic surgeons because of close relation of sphenoid sinus to surrounding important neurovascular elements.[3]

The foramen rotundum (Figure - 2) - Second branch of the trigeminal nerve (maxillary nerve) courses through this tiny canal situated in the skull base.[4] Lateral wall of sphenoid sinus forms its medial border. The canal later travels in an oblique fashion inferiorly and laterally. Hence acts as a communication way between the pterygopalatine fossa and middle cranial fossa.[5]

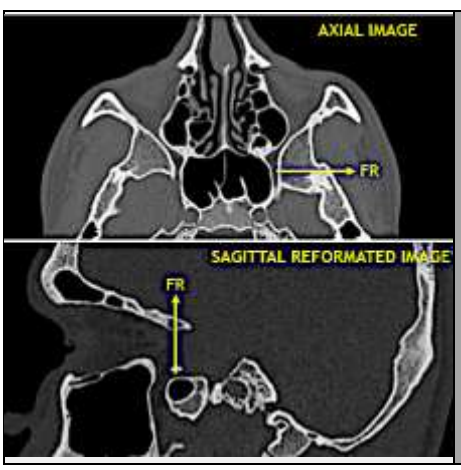

Figure 2. Axial and Sagittal Reformatted CT Bone Window Images at the Level of the FR (Foramen Rotundum)

The vidian canal (Figure - 3) travels through the medial pterygoid plate a part of sphenoid bone which later extends up to the pterygopalatine fossa from the foramen lacerum's ventral aspect, which lies in middle cranial fossa. Vein of the pterygoid canal, pterygoid canal nerve and artery (which are also known as the Vidian vein, nerve and artery respectively) are transmitted through this canal.

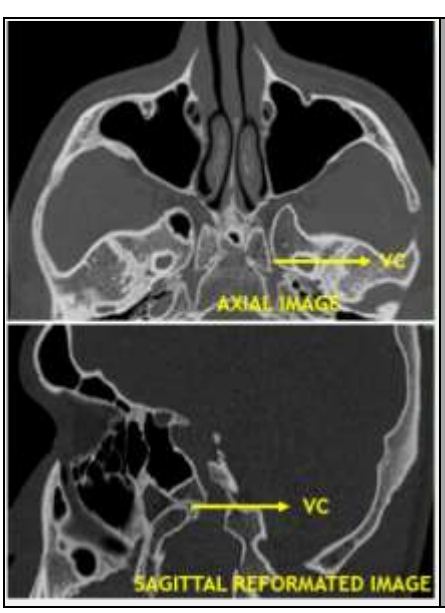

Figure 3. Axial and Sagittal Reformatted CT Images in Bone Window at the Level of the VC (Vidian Canal)

Acute alteration of disease outcome takes place when there is involvement of sphenoid sinus by pathologies especially tumour which acts as a driving factor for perineural spread. This necessitates a multidimensional treatment approach.[4]

Various landmarks are described to locate the important nerves and vessels surrounding the sinus after detailed study and development of new paradigms of anatomical relationships, hence avoiding their injury.[6] As a results of this paradigms novel endoscopic approaches are being designed for the skull base surgeries.

Objectives

1. To understand the relation between sphenoid sinus and its surrounding vital structures including foramen rotundum and vidian canal.
2. Helping endoscopic sinus surgeon for preoperative planning by describing various anatomical variations of foramen rotundum and vidian canal.

METHODS

This is a retrospective study conducted from November 2019 to March 2020 among 100 patients by analysing secondary data. CT scans of the Paranasal sinuses performed for any cause at Department of Radio diagnosis, Victoria Hospital, Bangalore Medical College and Research Institute, were reviewed retrospectively to look for the sphenoid sinus and its anatomical relationship to bilateral foramen rotundum and vidian canals.

Study Tools

All the CT scans were performed in our Philips Ingenuity 128 slice Multidetector Computed Tomography scanner. Coronal and sagittal planes are obtained from source axial images using Multiplanar reconstruction.

Slice thickness	3mm / 1mm thin slices
Pitch	<1
Gantry rotation time	1 second
kVp	120
mA	200
Reconstruction matrix	512 * 512
FOV (field of view)	18 cm.

Imaging Parameters

Radiological Method of Assessment

A. Foramen Rotundum Location

Radiological assessment in relation to the base of lateral pterygoid plate (Figure 4) -

a. Online – Foramen rotundum in relation to lateral pterygoid plate is tangentially placed;
b. Medial - Foramen rotundum in relation to lateral pterygoid plate is medially placed;
c. Lateral - Foramen rotundum in relation to lateral pterygoid plate is laterally placed.

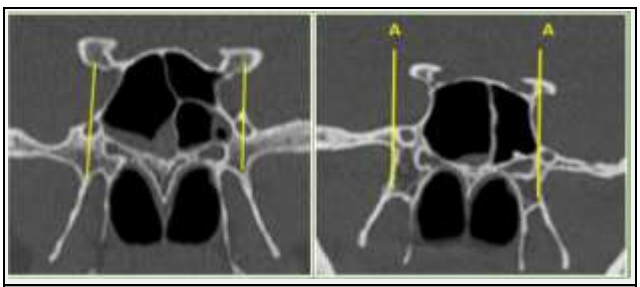

Figure 4. Position of Foramen Rotundum as Seen on Coronal Reformatted CT Images in Bone Window. First Image Shows Bilateral 'Online' FRs and Second Image Shows Right Sided Medial FR and Left Sided Lateral FR

Note - An imaginary tangential line is drawn to the lateral pterygoid plate base. Mid sphenoid position identification-determined in coronal section -According to various spaces such as nasal cavity, nasopharyngeal space and choana which lie below the middle of the sphenoid.

B. Radiological Assessment of Types of Foramen Rotundum

There are three types (Figure 5) -

Type I - Complete foramen rotundum lies within the sinus cavity.

Type II a - Foramen is partially protruding into the sinus cavity.

Type II b - Medial part of wall is tangential to the sinus cavity.

Type III - Foramen is surrounded on all sides by bone.

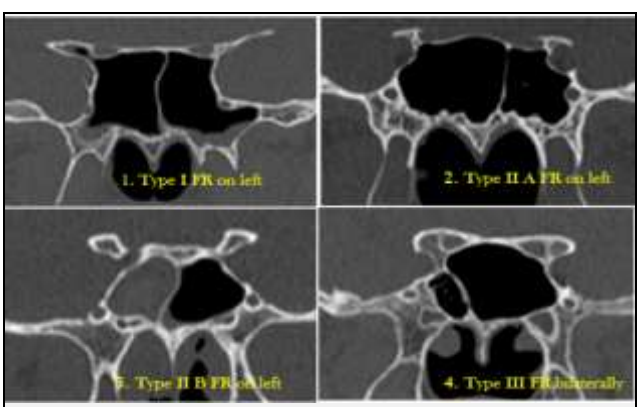

Figure 5. Types of Foramen Rotundum on Coronal Reformatted CT Bone Window Images

C. Radiological Assessment of Types of Vidian Canals

Three types based on CT findings (Figure 6) -

Type I - canal completely lies within the sinus cavity.

Type II - canal partially projects into the sinus cavity.

Type III - canal is surrounded on all sides by bone.

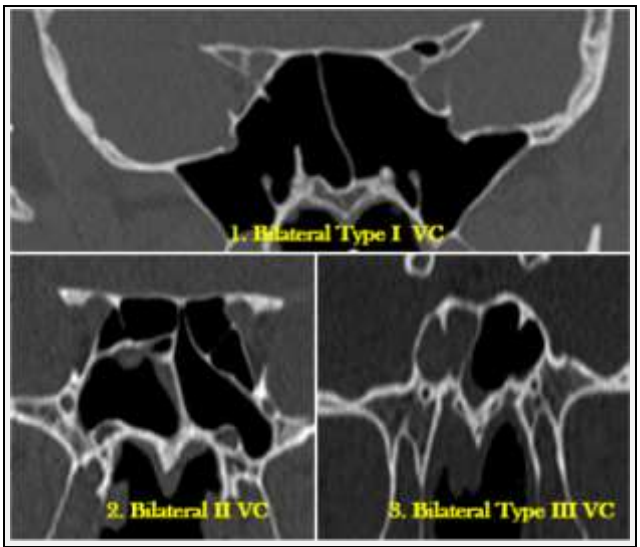

Figure 6. Types of Vidian Canal as Assessed on Coronal Reformatted CT Images in Bone Window

Statistical Analysis

Bivariate analysis was done to see the association between both sided foramen rotundum position and respective side vidian canal type and foramen rotundum type. Chi square test was applied with fisher's exact correction to see the association.

RESULTS

Type	Number of Patients Right	Left	Total in %
I	32	32	32
II	40	40	40
III	28	28	28
Distribution of Types of Vidian Canal			
I	6	6	6
IIA	32	32	32
IIB	44	44	44
III	18	18	18

Table 1. Distribution of Types of Foramen Rotundum

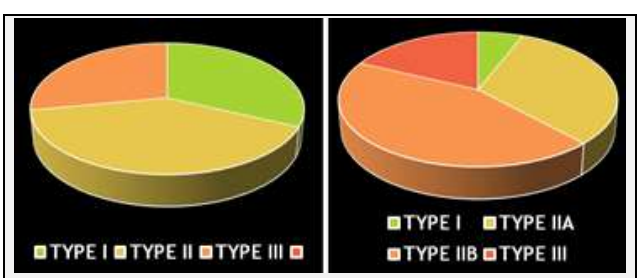

Figure 7a and 7b. Pie Chart Depicting Relative Percentages of Patients with Varied Vidian Canal Types (7a) and Foramen Rotundum Types (7b)

Types	Right in %	Left in %	Total in %
Online	48	52	50
Medially located	50	44	47
Laterally located	2	4	3

Table 2. Foramen Rotundum Position with Respect to Lateral Pterygoid Plate Base

Bivariate analysis was done to evaluate the association between both sided foramen rotundum position and respective side vidian canal type. Chi square test was applied with Fisher's exact correction to see the association. However, the difference was not statistically significant (Table 3).

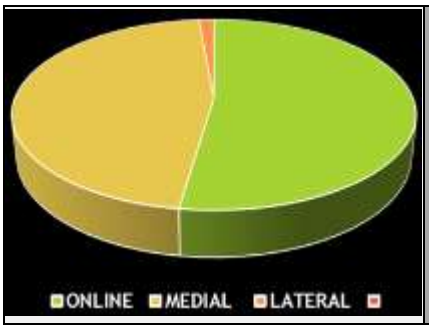

Figure 8. Relative Percentage of Patients with Varied Positions of Foramen Rotundum

Right Vidian Canal Type	Right FR Position N (%) Online	Medial	Lateral	Chi Square Test
Type I	18 (37.5)	12 (24)	2 (100)	Fisher's Exact value=9.5 Df=6 p value=0.104
Type IIa	1 (2.1)	5 (10)	0	
Type IIb	18 (37.5)	26 (52)	0	
Type III	11 (22.9)	7 (14)	0	
Total	**48 (100)**	**50 (100)**	**2 (100)**	-
Association between left side vidian canal type and left sided foramen rotundum position distribution				
Left Vidian Canal Type	**Left FR Position N (%) Online**	**Medial**	**Lateral**	**Chi Square Test**
Type I	3 (5.8)	3 (6.8)	0	Fisher's Exact value=2.096 Df=6 p value=0.897
Type IIa	17 (32.7)	13 (29.5)	2 (50)	
Type IIb	21 (40.4)	21 (47.7)	2 (50)	
Type III	11 (21.2)	7 (15.9)	0	
Total	**52 (100)**	**44 (100)**	**4 (100)**	**-**

Table 3. Association between Right Side Vidian Canal Type and Right-Side Foramen Rotundum Position

Bivariate analysis was done to study the association between both sided foramen rotundum position and respective side foramen rotundum type. Chi square test was applied with fisher's exact correction to see the association. However the difference was not statistically significant (Table 4).

Right FR Type	Right FR Position N (%) Online	Medial	Lateral	Chi Square Test
Type I	19 (39.6)	20 (40)	1 (50)	Fisher's Exact value=3.836 Df=4P value=0.448
Type II	12 (25)	19 (38)	1 (50)	
Type III	17 (35.4)	11 (22)	0	
Total	**48 (100)**	**50 (100)**	**2 (100)**	**-**
Association between left side foramen rotundum type and its position distribution				
Left FR Type	Left FR Position N (%) **Online**	**Medial**	**Lateral**	**Chi Square Test**
Type I	15 (28.8)	14 (31.8)	3 (75)	Fisher's Exact value=3.589 Df=4p value=0.349
Type II	23 (44.2)	16 (36.4)	1 (25)	
Type III	14 (26.9)	14 (31.8)	0	
Total	**52 (100)**	**44 (100)**	**4 (100)**	-

Table 4. Association between Right Side Foramen Rotundum Type and Its Position Distribution

DISCUSSION

Better surgical outcome experienced with endoscopic surgeries has led to wide spread usage of the technique for various surgeries. In the due course surgeons have also experienced that learning the anatomical variations is also important for the success of surgery.

In the study conducted by us radiological assessment of relationship between anatomical structures including foramen rotundum, vidian canal and sphenoid sinus was

done. As shown in Table 4, it is observed that foramen rotundum was placed online in ~ 50 % of the patients and medially placed in ~ 47 % of the patients and in 3 % of the total cases, foramens were placed laterally. From the study it is found that Online type and medial type are most common types. This is in direct agreement to a study conducted by Mohebbi A et al in 2017.[7]

The present study showed that Vidian canal and foramen rotundum classifications were same on either sides in most of the cases. It was found that the type of Vidian canal classification was always same as foramen rotundum type in most of the cases and one level less than the foramen rotundum type in few patients.

Example - 1 The foramen canal was either type I or type II, when the vidian canal was type I.

Example - 2 The foramen canal was either type IIa / b or type III, when the vidian canal was type II.

Bivariate analysis was done to see the association between both sided foramen rotundum position and respective side foramen rotundum type and vidian canal type (Table 3 and 4). Chi square test was applied with fisher's exact correction to see the association. However the difference was not statistically significant indicating non association of vidian canal and foramen rotundum types with foramen rotundum position.

The results of our study was found correlating with a study conducted by Mohebbi A et al,[7] where 48 % had type II, 28 % had type I vidian canal and 24 % had type III vidian canals compared to our study (32 %, 40 % and 28 % respectively). Furthermore, there was also a correlation in terms of the types of foramen rotundum in the study had 4 % type I, 28 % type II a, 44 % II b and 24 % type III. In comparison to this our study had 6 %, 32 %, 44 % and 18 % respectively.

Sphenoid sinus over pneumatisation make it more close to the adjacent structures hence risking those structures to injury during surgery. Over pneumatisation leads to extension of air filled sinus in between neurovascular bundle. For example, extension up to the base of pterygoid plate is nothing but extension in between nerve to pterygoid canal and 2nd branch of trigeminal nerve.

Superior and lateral to the wall of sphenoid sinus lies the most important structures like optic nerves and the internal carotid arteries. These structures are known to have varying courses in relation to sphenoid sinus.[3] The sphenoid sinus usually have a bony septum which result in formation of asymmetrical cavities inside sphenoid body. According to most of the literatures this septum will be most often situated laterally to one or the other side than being situated in the median plane. Most of the sphenoid sinus pathologies are treated by endoscopic approach with only few exceptions. Because of it crucial relationship to skull base, it is often used as a pathway to middle cranial fossa and other adjacent vital structures by otorhinolaryngologists and neurosurgeons and it has also led to development of innovative approaches. Being highly variable in its anatomical relationship, knowledge of the same is of utmost important in preoperative planning of any procedures.[3] Hence it is necessary to apprise surgeons about these variations. Most of the vital surgical complications can be prevented by this.

Endonasal endoscopic surgery is also needed to deal with various pathologies associated with trigeminal nerve (including nerve sheath tumours, meningeal tumours, secondary involvement in malignancies), Pathologies associated with cavernous sinus (like thrombosis, caroticocavernous fistula and nerve sheath tumours) and other pathologies of middle cranial fossa like pseudomeningocele and CSF leak. All this afore mentioned pathologies needs diagnostic evaluation like biopsy and therapeutic evaluation like decompression surgery, which is done by endoscopic approach via endonasal route. Sphenoid sinus acts as a hall for all these surgeries because of its location below sella turcica and close association with Meckel's cave, cavernous sinus, orbital apex and pterygopalatine fossa.[8]

Large number of studies were conducted till date for better definition of anatomical relationship of sphenoid sinus. Because anatomical relationship will vary among communities in particular geographic area, it is always better for the surgeon to take into account the study conducted on a particular population while doing preoperative planning. Our study helps the surgeon to know about the most common types of this anatomical variation in the patients who visit Victoria hospital.

Here is a brief review of various literature proposed till today which has led to development of new techniques in the field of endoscopic surgery -

a. In a study conducted by Wang et al, he proposed a new classification system for extension of sinus including clival, lesser wing, and lateral, anterior, and combined type by studying computed tomography images of 100 and 18 Sphenoid sinuses in adults and cadavers, respectively.[9]
b. In another study conducted by Vescan et al. he described correlation between ICA and vidian canal after analysing 44 patients using computed tomography images which enhanced knowledge about Vidian canal anatomy and its relationships to known surgical lead points in skull base endoscopic surgeries.
c. In a study conducted by Kasemsiri et al. by reviewing images from Maxillofacial HRCT scans he defined various surgical lead points for the pre-operative planning of transpterygoid approaches using endoscopy.
d. In a study conducted by Vaezi et al. he proposed a classification system using HRCT scans in coronal plane on the ground of degree of pneumatization of sphenoid sinus.

Eventually the final aim of all the aforementioned studies and the similar study conducted by us is to give a better understanding of this composite area and anatomical variations of it's structures, which helps in finer preoperative planning for endonasal surgeries by endoscopic approaches, which will lead to better prognosis in patients post treatment by evading neurovascular complications.

CONCLUSIONS

This article sheds more light on the anatomy of foramen rotundum along with the other anatomical / surgical lead points used in endonasal surgeries such as lateral pterygoid plate and vidian canal. The study results aid endoscopic skull base surgeons to know the most common types of anatomical variations which help in better understanding of this complex area prior to surgery resulting in better prognosis. In order to generalise the study results, the same study has to be conducted on a larger population by incorporating clinical entities which ensure a better knowledge on skull base anatomy.

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