T.C.

BAHÇEŞEHİR UNIVERSITY

EVALUATION OF NEUROVASCULAR STRUCTURES ACCORDING TO SPHENOID SINUS VARIATIONS USING CONTRASTED HYPOPHYSEAL MRI

Master's Thesis

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Director of the Institution
Signature

This is to certify that we have read this thesis and we find it fully adequate in scope, quality and content, as a thesis for degree of Master of Arts.

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PREFACE

In the name of Allah, firstly all the praise and thanks to Allah who continuing blessing me to achieve this work by only Allah mercy and grace. I would like to acknowledge my home country, Libya, for honoring me a scholarship to get a Master degree in Bahcesehir University in Turkey. I would specifically like to express my gratitude to my supervisor, Dr. Melike Yavuz for her excellent supervision. My sincere thanks to the Radiology department staff for their invaluable guidance for conducting this research namely, Prof. Dr. Mustafa Kemal Demir; Dr. Umut Özdamarlar. I would particularly thank Dr. Timuçin Avşar, the head of department, for his cooperation and suggestions.

Special thanks for my wonderful parents for their love and encouragement. I would like to thank my husband for the endless amount of help. My thanks for my lovely daughters who have always been inspired.

Finally, great remembrance for all cancer patients. I would like to transfer message for them that cancer does not mean life ends; however, cancer is a new experience that makes you stronger.

ABSTRACT

EVALUATION OF NEUROVASCULAR STRUCTURES ACCORDING TO SPHENOID SINUS VARIATIONS USING CONTRASTED HYPOPHYSEAL MRI

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Sphenoid sinus is the most inapproachable paranasal sinuses, lie within the body of sphenoid bone and enclosed by vital neural and vascular structures. Anatomically sphenoid sinus varying in size and shape. The prevalence of these variation changes according to age and sex. Detail understanding of anatomical variation is important for optimal patient care. This is a retrospective study investigate the prevalence of sphenoid sinus variation using MRI scan of pituitary gland for patient aged from 14-70 years at Bahcesehir University Hospital (Medical Park) in Goztepe/Istanbul, from first of June 2015 to thirty-first of July 2019. A total of 204 hypophyseal MRI scan was analyzed for sphenoid sinus volume, number of septae and its insertion site, type of pneumatization, optic nerve and internal carotid artery protrusion, and inter optic and inter carotid distance. The mean volume of the sphenoid sinus was 23.4cc. Single septa was prominent among study population (61.8percent) and the principle attachment site of the septa was sella (40.2percent). The commonest types of pneumatization was the post sellar type 58.3percent. The majority of optic nerves were protruding 43.6percent. The ICA in relation to the sphenoid sinus was seen protruded in most of cases (frequency 53.9percent). The mean inter-optic nerve distance just after coming from optic foramen was 11.84mm, prechiasmatic inter-optic nerve distance was 7mm. The distance between two cavernous carotid arteries was 20.53mm, inter-distance between paraclinoid carotid arteries was 13.72mm. the distance between optic nerves and the distance between carotid arteries was more in larger sphenoid sinus. This study shows that, the sinus volume effect the protrusion of optic nerve and the distance between two optic nerves and carotid arteries. The result of this study can assist the neurosurgeon and otorhinolaryngologist to decrease possible complications in trans-sphenoidal surgery by routine description of the sphenoid sinus and related neurovascular structures variations in the imaging report.

Keywords: Sphenoid Sinus, Pneumatization, Inter Optic Distance, Inter Carotid Distance

ÖZET

NÖROVASKÜLER YAPILARIN SFENOID SINÜS VARYASYONLARINA GÖRE KONTRASTLI HIPOFIZ MRG KULLANARAK DEĞERLENDİRİlMESİ

Fatma Alfageih

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Ocak/2019,82 sayfa

Sfenoid sinüs en ulaşılmaz paranazal sinüslerdir, sfenoid kemik gövdesi içinde yer alır ve hayati sinir ve damar yapıları ile çevrilidir. Anatomik olarak sfenoid sinüsün büyüklüğü ve şekli değişir. Bu varyasyonun sıklığı yaş ve cinsiyete göre değişir. Optimal hasta bakımı için anatomik varyasyonun ayrıntılı olarak anlaşılması önemlidir. Bu, Göztepe/İstanbul'da, Bahçeşehir Üniversitesi Hastanesi'nde (Medical Park), 14-70 yaş arası 1Haziran 2015 -31 Temmuz 2019 tarihleri arasında, 14-70 yaş arası hastaların hipofiz bezi MRG kayıtları kullanılarak sfenoid sinüs varyasyonunun yaygınlığını araştıran retrospektif bir çalışmadır. Toplam 204 hipofiz MRG incelemesi, sfenoid sinüs hacmi, septa sayısı ve yerleşim bölgesi, pnömatizasyon tipi, optik sinir ve internal karotid arter çıkıntısı, inter-optik ve inter-karotid mesafeleri açısından analiz edildi. Sfenoid sinüsün ortalama hacmi 23.4 cc idi. Çalışma popülasyonunda tek septa yaygındı (% 61.8) ve septanın temel bağlanma bölgesi çoğunlukla sella (% 40.2) idi. Pnömatizasyonun en yaygın tipi yüzde 58.3 ile post sellar tip idi. Optik sinirlerin çoğunluğu (%43.6) protrüzyon yapıyordu. Internal Karotid Arterlerin çoğu olguda, sfenoid sinüs ile ilişkili olarak protrüzyon yaptığı görülmüştür (sıklık % 53.9). Optik foramenlerden çıktıktan hemen sonra iki optik sinir arası mesafe ortalaması 11,84 mm, prekiazmatik optic sinirler arası mesafe ortalaması 7 mm'dir. İki kavernöz karotid arter arasındaki mesafe 20,53 mm, paraklinoid karotid arterler arasındaki mesafe 13.72 mm'dir. Optik sinirler arası mesafe ile karotid arterler arasındaki mesafe sfenoid sinüsler büyüdükçe artmıştır. Bu çalışma sfenoid sinus hacminin optic sinirin protrüzyonunu etkilediğini ve sinus hacmi ile optic sinirler arası mesafe ve carotid arterler arası mesafe arasında ilişki olduğunu göstermiştir. Bu çalışmanın bulguları, nöroşirürji ve kulak burun boğaz uzmanlarının, görüntüleme raporlarında sfenoid sinüs ve ilişkili nörovasküler yapı varyasyonlarının rutin olarak tanımlanması ile transsfenoidal cerrahide olası komplikasyonların azaltılmasına yardımcı olabilir.

Anahtar kelimeler: Sfenoid Sinüs, Pnömatizasyon, İnter-Optik mesafe, İnter-Karotid Mesafe

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ABBREVIATIONS

SS	:	Sphenoid Sinus
MRI	:	Magnetic Resonance Imaging
CT	:	Computed Tomography
PNS	:	Paranasal Sinuses
ON	:	Optic Nerve
ICA	:	Internal Carotid Artery
SS	:	Sphenoid Sinus
ETSS	:	Endoscopic Transsphenoidal Surgery
IOD	:	Inter Optic Distance
ICD	:	Inter Carotid Distance
IOND	:	Inter Optic Nerve Distance
PICD	:	Paraclinoid Inter Carotid Distance
CICD	:	Cavernous Inter Carotid Distance
mm	:	Millimeter
CC	:	Cubic Centimeter
STD	:	Standard Deviation
P	:	Probability
CTA	:	Computed Tomography Angiography

SYMBOLS

The coefficient correlation : r^2

1. INTRODUCTION

1.1 SUMMARY OF THE STUDY

Sphenoid sinuses (SS) are a double air cavity situated within the body of the sphenoid bone. It is enclosed by vital structures, that are disconnected by its tinny bony walls. These structures are the internal carotid artery, pituitary gland, optic nerve, pterygoid nerve and maxillary nerve.

Its deep-seated, that makes the approaching way to the sinus risky. Furthermore, sphenoid sinus is considered as one of the most dissimilar structures. They differ in shape, size, septation, and relationship to surrounding neurovascular structures. Accordingly, comprehensive acknowledgment of these differences can decrease any possible hazards. Additionally, the expansion of the transsphenoidal sinus approaches for managing the anterior skull base lesions, clivus and perisellar region through the sphenoid sinuses, ultimately rise the clinical importance of sphenoid sinuses.

The present study had assessed the volume of sphenoid sinus, number and the attachment site of the sinus septa, difference in pneumatization types using Hammer and Radberg classification, protrusion of both optic nerve (ON) and internal carotid artery (ICA) into the sinus cavity, the distance separating intracranial optic nerves, and distance separating cavernous and paraclinoid segments of ICA. This research was conducted by reviewing hypophyseal magnetic resonance imaging (MRI) scan from the Radiology Department at Bahcesehir University Hospital (Medical Park Göztepe) in Istanbul. The thin slice (2mm) T2-weighted and T1-weighted images of the cases who justify our inclusion standards were reassessed in coronal, and sagittal planes respectively.

The images were reviewed and the measurements were done using Synapse three-dimensional (3D) PACS software. Statistical analysis using the t-test, and chi-square was done. The results show the average volume, number of septae, the frequency of the pneumatization types, ON and ICA protrusion into the SS, the average of inter optic and inter carotid distance.

1.2 THE STUDY BACKGROUND

The advancement of medical tools and techniques for example the new imaging technique and functional endoscopic sinus surgery require a full understanding of the anatomy of the sinuses and its variations. Transsphenoidal procedures allowed the approaches to sphenoid sinus with minimally forceful surgery to treat and access to anterior skull base structures, the pituitary gland, clivus, presellar area, and cavernous sinus. Preoperative imaging evaluation reduces the possible injury from the surgery in these regions (Ramalho et al. 2017, pp. 162–167).

The sphenoid sinus is surrounded by significant structures like the cavernous sinus and the orbit and their contents; anterior cranial fossa, internal carotid artery, and optic nerves. Furthermore, there is substantial dissimilarities among population in the sphenoid sinus morphology and itis defined anatomical points. Growing the use of transsphenoidal endoscopic surgery proper evaluation of the anatomical variability of the SS and its surrounding neurovascular structures is essential (Unal et al. 2006, pp. 195–201).

A study was done by Kashyap et al. (2017, pp.955-959) used paranasal sinus computed tomographic scan to evaluate sphenoid sinus septation, ICA relation. They reported that the most of population with single septate sphenoid sinuses and the majority of septa were inserted to internal carotid artery (Kashyap et al. 2017, pp .955–959).

This research assessed the sphenoid sinus volume, septation numbers and site of attachment, pneumatization criteria, ON and ICA protrusion in to the sinus cavity, and inter optic and inter carotid distance using pituitary MRI scan for patients aged from 14-70 years.

1.3 STATEMENT OF THE PROBLEM

Growing the use of transsphenoidal endoscopic approach arrogate a detailed knowledge of the sphenoid sinus anatomical differences and enclosed structures is considerably significant (Unal et al. 2006, pp. 195–201).

Endoscopic Trans Sphenoidal Surgery (ETSS) tools uses in the management of paranasal sinuses, middle brain and orbital diseases needs a detailed acknowledge in the sinus anatomical structures, and its relationship to neurovascular structures and pituitary gland. And because of the anatomical dissimilarity of sinuses happens not only between people but as well within the same person between both sides.

Because the orbit and paranasal sinuses contain air, fat, bone, and soft tissue, that makes the contrasting density high, which need more exactness of radiological assessment. Consequently, the full radiological examination of the sinuses preoperatively diminution the hazard of the surgery (Mendiratta et al. 2016, pp. 352-358).

The most serious complications of Endoscopic Trans Sphenoidal Surgery (ETSS) comprise, optic nerve trauma, arterial vascular damages, orbital hematoma, nasolacrimal duct damage, and cerebrospinal fluid leak. These complications can be eliminated by routine preoperative and intraoperative use of computed tomographic (CT) scan imaging. A new review informed the frequency of complication is about 0.36-1.3percent (O'Brien , Hamelin, and Weitzel 2016, pp.10-21).

1.4 REASONING OF THE STUDY

An appropriate recognition of the anatomical structures of the sinuses and their relation to nerves, vessels and gland is an essential demand for use of ETSS. The endoscopic surgeries are not lake of difficulty.

Consecutively, prevention of destructive complication and increase effectiveness and care of ETSS, a precise and accurate acknowledge of the anatomical dissimilarities in this complex area is indispensable. This can be attained by a good preoperative examination of the sinuses and related structures. Although most of preceding researches on the anatomical variation of the sphenoid sinus were performed by using CT scan, that need different patient positions. MRI scan provides all details of sphenoid sinus variations in one image set. It gives a much better image of the pituitary gland and surrounding soft tissue structures, which could not be achieved using other types of scans. MRI scan nowadays has the highest develops in radiology as it offers a highly developed image value in the remaining machineries. However, sphenoid sinus variations differ from population to another thus these variations were studied worldwide. The following study is planned to investigate all the anatomical variations of the sphenoid sinus and surrounding neurovascular structures using MRI of the pituitary gland.

1.5 PURPOSE OF THE STUDY

This research directed to reveal the prevalence of sphenoid sinus variations. And the object is to determine these variations using MRI scan of the pituitary gland. It also provided a broad radio-anatomical view of the sphenoid sinus variations and it is related neurovascular structures.

1.6 AIMS OF THE STUDY

The present study aims to attain the next objects

i. Measurement of the sphenoid sinuses volume.
ii. Evaluation of the number of the sinus septa and determine its site of attachment.
iii. Evaluation of the pneumatization types of the sphenoid sinuses.
iv. Assessment of the prevalence of optic nerve and internal carotid artery protrusion.
v. Measurement the distance between intracranial optic nerves.
vi. Measurement the distance between cavernous ICAs.
vii. Measurement the distance between paraclinoid ICAs.

1.7 RESEARCH QUERIES

i. What is the normal rang volume of sphenoid sinus among adult?
ii. What is the majority of attachment site of the sinus septa?
iii. What are the most frequent variations of the sphenoid sinuses?
iv. How frequent are the optic nerve protrusion among study population?
v. How frequent are the internal carotid artery protrusion among study population?
vi. What is the distance between intracranial optic nerves?
vii. What is the distance the separating distance between cavernous ICAs?
viii. What is the distance the separating distance between paraclinoid ICAs?
ix. Is there any significant anatomical variation of the sphenoid sinus between male and female?

x. Is there any significant relation between sphenoid sinus volume and protrusion of surrounding neurovascular structures?

xi. Does sphenoid sinus volume significantly relate with the distance between ONs and ICAs?

1.8 RESEARCH HYPOTHESIS

Sphenoid sinus volume is related with optic nerve and internal carotid artery protrusion, and it is positively correlated with the inter optic nerve distance and inter-carotid artery distance.

1.9 IMPLICATION OF THE STUDY

The sphenoid sinus variation analysis benefits the radiologist, ophthalmologist, the otolaryngologist, and neurosurgeon in expecting the risk of the complication during the trans sphenoidal surgery.

Sphenoid sinus deemed as an entryway for surgeons to access surrounded structures. Consequently, the sphenoid sinus is an important diagnostic and treatment structure to oppose several diseases.

This research can enhance the use of preoperative MRI assessment of the sphenoid sinus for any trans sphenoid sinus surgery. Additionally, the sphenoid sinus variation frequency might be a useful information in the field of forensic medicine.

2. LITERATURE REVIEW

2.1 THE SPHENOID SINUS GROSS ANATOMY

The nasal cavity is bounded by a numeral bone, and inside some of these bones are air-filled sacs known as paranasal sinuses. The sphenoid sinus is most inaccessible paranasal sinuses located within the sphenoid bone body. The pair is disconnected by a septum that often deviated from midline and makes them dissimilar in the shape and size. The bigger one is asserted as dominant sinus. The non-dominant sinus (smaller) situated in front the pituitary fossa, although the dominant sinus might enlarge to reach pterygoid process and the greater wing of the sphenoid (Viday and Raichurkar (2015), Anusha et al.(2014, PP.419–427)).

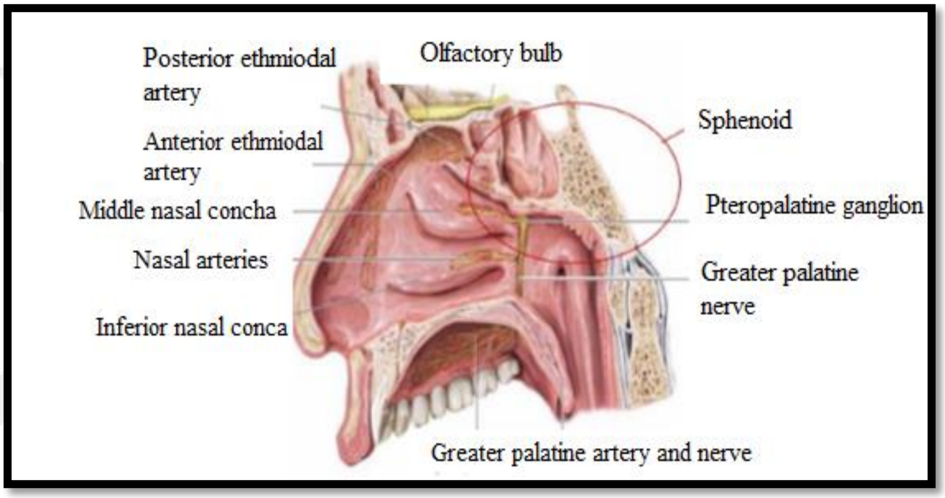
In addition, sphenoid sinuses opens in to the upper wall of the nasal cavity via the sphenoethmoidal recess(Elwany et al. 1983 ,pp. 227–241). It is enclosed by vital structures the middle cranial fossa, pituitary fossa and planum sphenoidale are located superiorly, the cavernous sinus and its neurovascular content and infratemporal fossa are located laterally and the clivus, posterior cranial fossa, brain stem, and basilar part of the occipital bone are located posteriorly as illustrated in Figure 2.1 and Figure 2.3(Palmer and Chiu 2012).

Inferiorly, the nasopharynx roof is related to the sinus. Inferiorly superolaterally, the second cranial nerve is closed to the sphenoid sinus, while, internal carotid artery posterolaterally (Figure 2.2) and the vidian and maxillary nerves inferiorly. There is small depression between the carotid artery and optic nerve named carotico-optic recess(Anusha et al. 2014, PP.419–427).

The nasal cavity and all paranasal sinus including sphenoid sinus are lined by ciliated respiratory-type epithelium, which comprised of cells with cilia, cells without cilia. Goblet cell**s**, and basal cells ,transient immune cells; lymphocytes and mast cells(Cardesa et al. 2016 ,pp. 49–127).

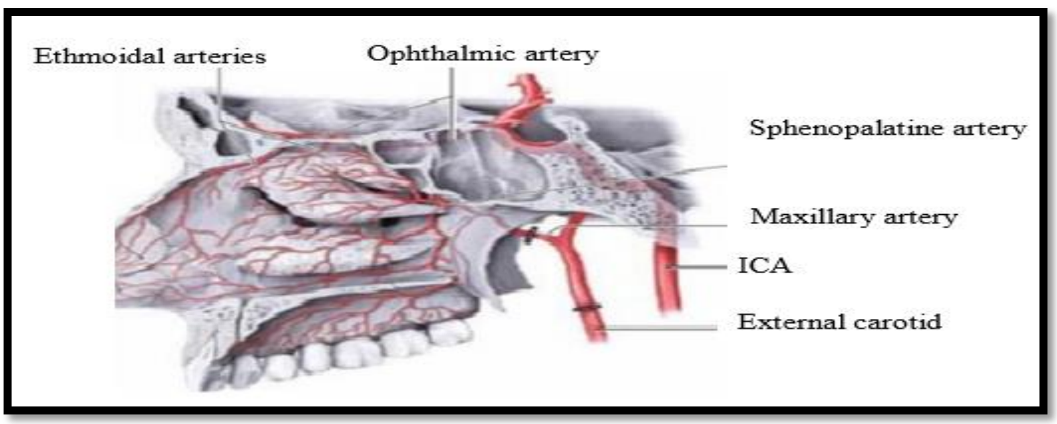
The arterial supply of the sphenoid sinus is provided by nasal branches of palatine and posterior ethmoidal artery (Figure 2.2). Whereas, the venous blood drained from the sinus via posterior ophthalmic vein by its posterior ethmoidal branch. The sinus lymphatic drained to the retropharyngeal lymph node by the afferent lymphatic vessels (Cappello and Dublin 2018). Moreover, the sphenoid sinus mucosa is receiving sensory innervation by division from parasympathetic pterygoid ganglion and sympathetic sensory nerves through posterior ethmoidal division from nasociliary nerves and another branches from ophthalmic division of the trigerminal nerves(Inamasu and Guiot, 2005, pp. 239–247).

Figure 2.1: Schematic diagram of sphenoid sinus anatomy



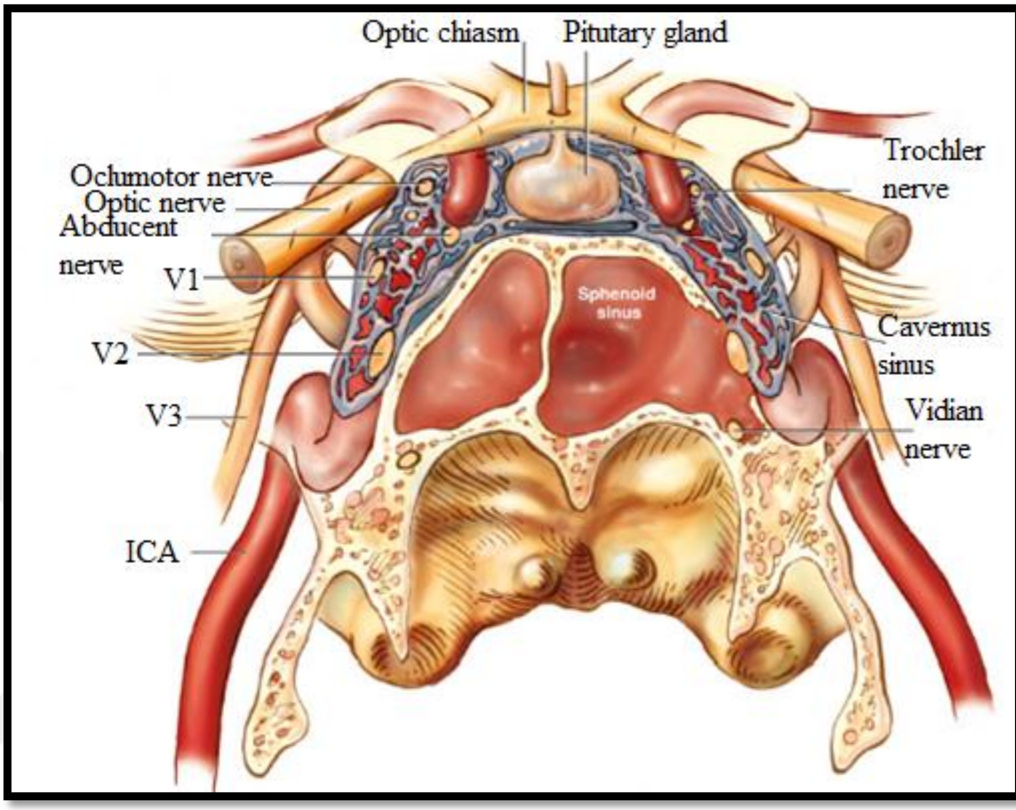
Source: This figure was taken from (Schuenke et al. 2010)

Figure 2.2: Arterial blood supply of the sphenoid sinus and internal carotid artery relation



Source: This figure was taken from (Schuenke et al. 2010)

Figure 2.3: Sphenoid sinus anatomical relation



ICA: Internal carotid artery
V1: Ophthalmic
V2: Maxillary division
V3: Mandibular division of trigerminal nerve
Source: This figure was taken from(Bleier and Schlosser 2019, pp. 233–242)

2.2. SPHENOID SINUS DEVELOPMENT

Newly hypotheses have confidence in that the skull base bones mostly originates from cartilaginous ossification centers with a slight membranous origin as the base of the skull is principally developed by sphenoid bone which encompasses the body, greater and lesser wings and pterygoid plates.

Every sphenoid bone part has its definite and compound ossification centers. The body of sphenoidal originated from presphenoidal and post-sphenoid centers lengthwise with the involvement of medial crus of orbitosphenoid center. Whereas the lesser and greater wings of the sphenoid derived from the orbitosphenoid and larger alisphenoid centers. Medial and

Lateral pterygoid plates have their own ossification centers which are endochondral and intramembranous centers respectively (Figure 2.4).

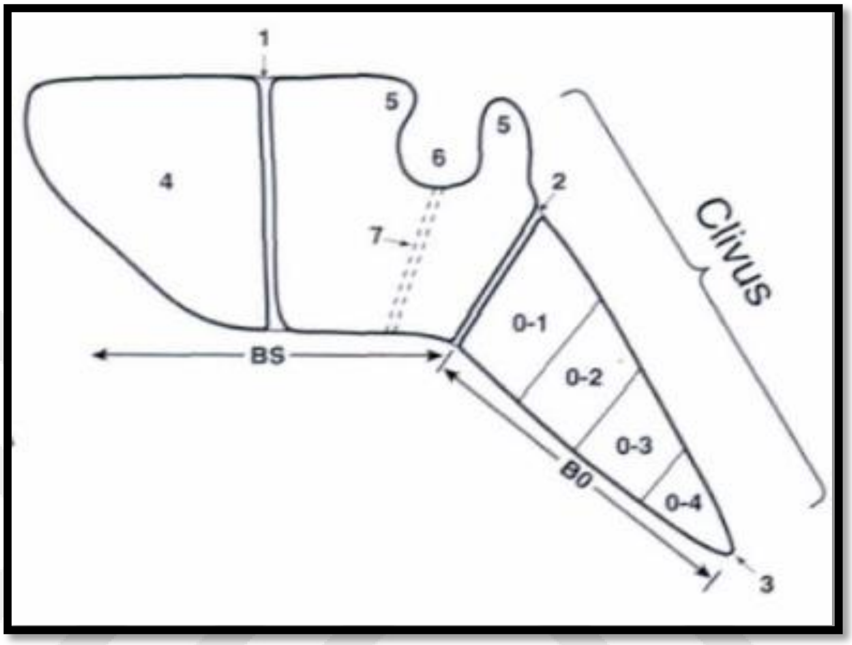
The rostrum of the basisphenoid enclosed by two ossification pairs called bone of Bertin. That is the original area of sphenoid pneumatization(Budu et al .2013) . Throughout the development of fetus, the sphenoid sinuses bone originated from paraxial mesoderm and neural crest (Tubbs , Salter and Oakes 2007, pp. 131–134) . the development of sphenoid sinus begins in the second trimester of pregnancy by invagination of fetal posterior nasal capsule through the sphenoid bone(Baskin et al. 2003, pp. 168–172, Hwang and Abdalkhani 2003, p. 455).

At initial period after birth sphenoid sinus block up with only red erythropoietic bone marrow. After that it changed to yellow bone marrow between 7months and 2 years in the presphenoidal plate, and it continues to expand posteriorly to reach the sphenoidal base plate (Anusha et al. 2014, PP.419–427).

The sinus obviously starts to pneumatize at three years old, whereas the aeration of the body of the sinus advancement(Baskin, Kuriakose and Lebowitz. 2003, pp.168–172), and the pneumatization starts at the sella turcica at seven years old (Kashyap et al. 2017, pp .955–959).

The sinus aeration grow up at a rate of 0.25 mm per year .However, the rate of growth then is not constant, it attains their maximum volume by the age of 18 years (7.3 cc)(Kashyap et al. 2017, pp .955–959, Baskin, Kuriakose and Lebowitz. 2003, pp.168–172).In adults, the grade of pneumatization, septation and neurovascular intrasphenoidal protrusions are significantly various (Kashyap et al. 2017,pp.955-959) .

Figure 2.4: Schematic diagram of central base of the skull and clivus component with their precursor's embryology



BO: basiocciput;
BS: basisphenoid
1: Anterior intrasphenoid synchondrosis
2: Sphenooccipital synchondrosis
3: Basion
4: Presphenoid ossification center
5: Sphenoid ossification center
6: sella turcica
7: Pharangohypophyseal region
Source : This figure was taken from (Jinkins, 2000)

2.3 SPHENOID SINUS PHYSIOLOGY

The function of the sinuses not well recognized, as the sphenoid sinus lined by pseudostratified epithelium containing goblet cells that produce mucus((Baskin, Kuriakose and Lebowitz. 2003, pp.168–172). It's been supposed that the sinuses act as moisture to the inspired air and adjusting its temperature and play a role in production of mucin to the respiratory way. The mucus which produced by goblet cells in the proper viscosity (thickness, stickiness) and amount, is the key to the system of mucociliary clearance working normally. Mucociliary clearance is the holy grail for healthy sinuses and that achieve respiratory health.

Besides, the sinuses play an important role in enhancing the verbal resonance and protect the upper part of the nasodigestive tract from rising tension. Furthermore, the sinuses pneumatization reduce the weight of the skull bones.

The mucin secretion in the nose passes into the nasopharynx along with mucous secretion of the paranasal sinuses in every ten to fifteen minutes. This enactment of the mucin movement is occurring as a result of the pseudo columnar epithelium ciliary movement. normally the cilia contact fifteen times in one second. The cilia movement is significantly diminished at 50percent decrease air moister, or at lower degree of temperature. the regular disappearance of the mucin strongly related to the sinus ostia opening, a proper quantity of mucin, and movement of cilia. The formed mucus in the sphenoid sinus is drained throughout the sphenoethmoidal recess into nasopharynx (Baskin, Kuriakose and Lebowitz. 2003, pp.168–172).

2.4 OPTIC NERVE ANATOMY

Optic nerve, second cranial nerve, that conveys sensory nerve signals from more than one million ganglion cells (GC) of the retina in the direction of the visual centers in the brain (Jonas et al. 1992). Also is extension of the central nervous system white matter, that pass with through optic canal into the orbit. It is enclosed by the meninges and is surrounded by cerebrospinal fluid which enters the subarachnoid space by the chiasmal cistern. The huge majority of optic nerve fibers, which formed by GC axons carry information concerning central vision(Forrester et al. 2015).

Anatomically the nerve can be divided into four parts as illustrated in Figure 2.5:

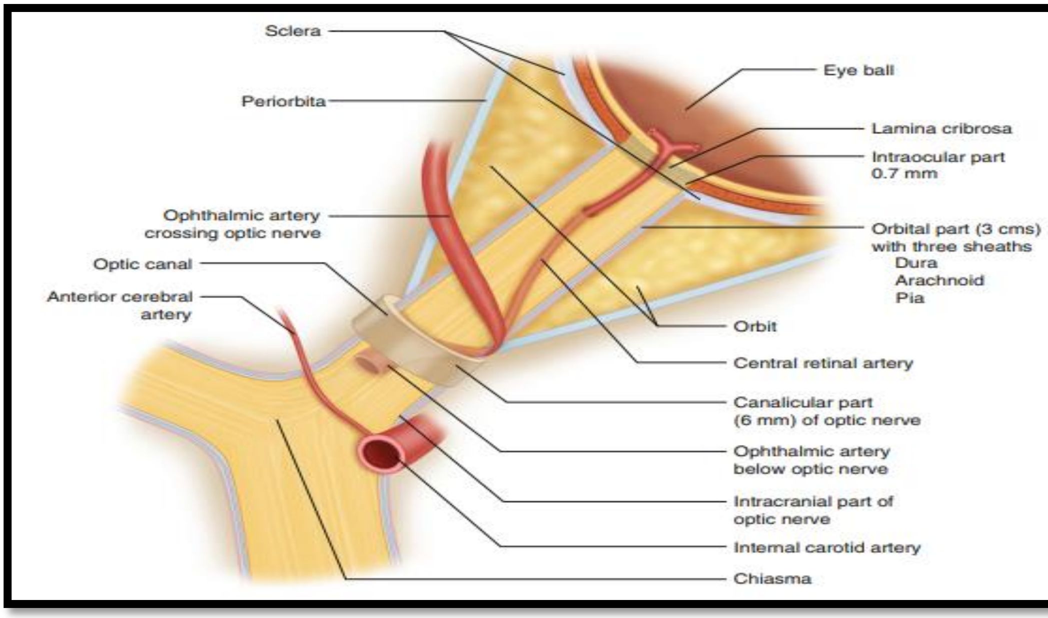
1. The intraocular segment, is about one millimeter in length. segment that is located within the eyeball(Salazar et al. 2018).

2.The intraorbital segment is about thirty millimeter in length. going from the eyeball posteriorly and enter the optic canal at their intraorbital opening .Likewise, this segment is enclosed by all three meningeal layers (Killer et al. 2003, pp. 777–781).

3.The intracanalicular segment, is furthermost inconstant, the average length is from four up to ten millimeters. The lesser wing of the sphenoid bone contains the optic canal (Rene 2006). The thickness of the walls of the optic canal is significant variable.

4.The prechiasmatic(Intracranial segment) is ranging from ten to sixteen millimeter (Forrester et al. 2015). Passing from the optic foramen superior to the diaphragma sellae, then it runs above the suprasellar aspect of the cavernous_sinus, the pia mater is the only covering layer . In this segment the optic nerve joins the other optic nerves forming the optic chiasm.

Figure 2.5: Schematic diagram of various parts of the optic nerve

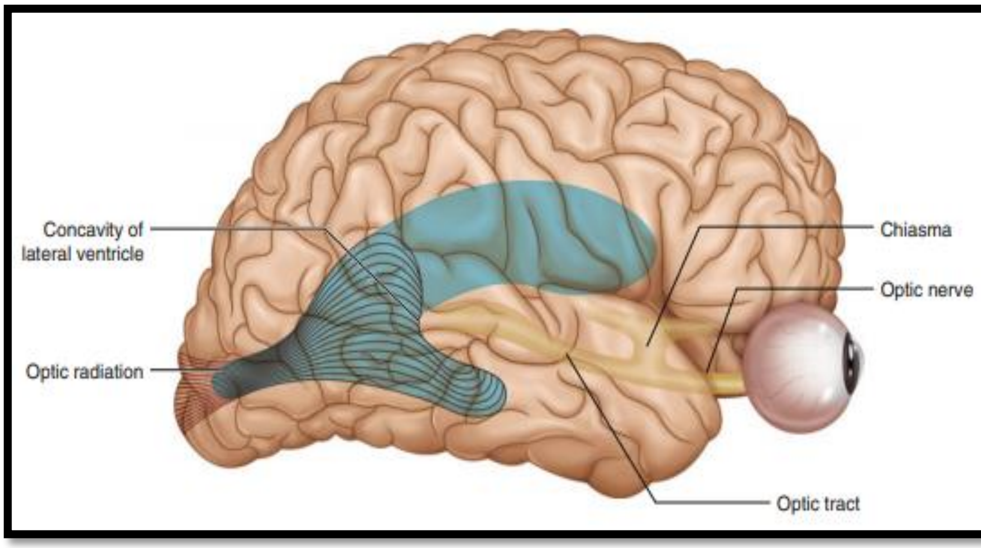


Source : This figure was taken from (Ansari and Nadeem, 2016)

Optic chiasma situated about ten millimeters directly superior to the pituitary gland. In around 80percent of the adults, its lei straight above the sella. Though, it might locate over tuberculum sellae in 10percent, and above dorsum sellae in the other 10percent of the population. the optic nerve is shorter and the optic tract is longer in the prefixed chiasma. While, vice versa in the postfixed chiasm (Campbell and DeJong 2005). Pituitary stalk angle is 90° or more in prefixed optic chiasm and acute angle for normal or postfixed chiasm(Griessenauer, Raborn and Mortazavi 2013).

From the optic chiasma, optic tracts path posterolaterally lengthways the cerebral peduncles to synapse at lateral geniculate bodies. From the lateral geniculate nuclei, optic radiations radiate out as optic radiations and reach the primary visual cortex (V1)in the occipital lobes (Figure 2.6) (Salazar et al. 2018).

Figure 2.6: Schematic diagram of optic nerve and visual pathway



Source *: This figure was taken from(Ansari and Nadeem, 2016)***.***

2.5 Internal Carotid Artery Anatomy

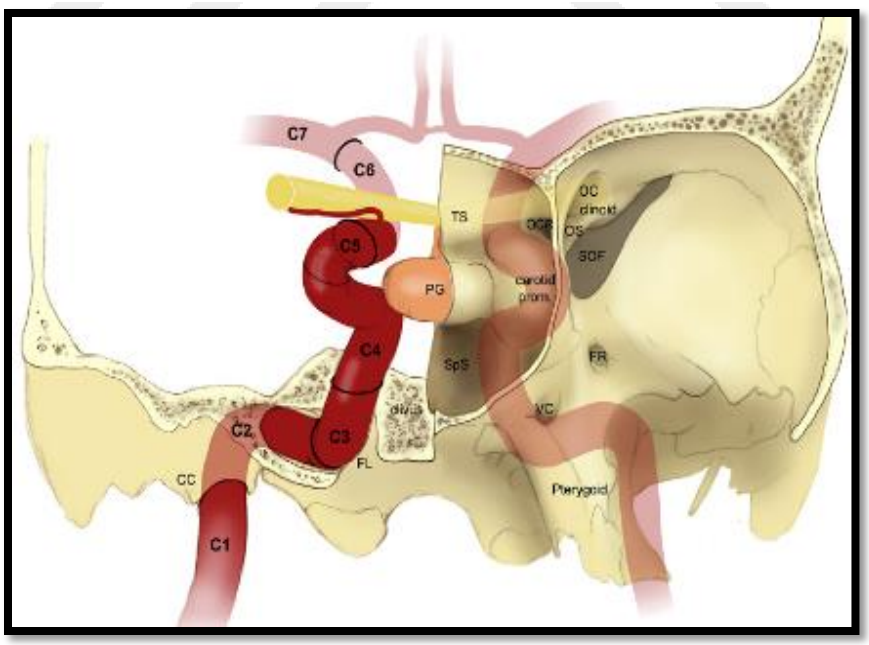
The internal carotid artery is a main branch of the common carotid artery, originate from the carotid bifurcation at a alongside the fourth cervical vertebrae supplying different parts of the head , the furthermost vital one is the brain.

On each side of the neck ,there is one internal carotid arteries. travel through the carotid sheath, run upward and enter the skull through the carotid canal located in the petrous portion of the temporal bone just superior to the jugular fossa(Webb and Adler, 2016).

Many branches are originated from ICA lengthwise its passage, eventually gives rise to its terminal branches. The anterior cerebral artery, and middle cerebral artery, which carries 80percent of the internal carotid blood flow , they form the anterior part of circle of wills, which is responsible for supplying the forebrain (Johns 2014). Moreover, ICA gives raise to numerous arteries supplying the , forehead, certain parts of the nose and the eye.

There are many classifications for internal carotid artery. One divide up the artery into four segments ,named according to the anatomical structures that ICA runs through: cervical segment, petrous segment, cavernous segment, and intercranial segment (Olivetti, 2014). Nowadays, the most widely used one divides ICA into seven parts which are seen in Figure 2.6 ; Cervical part, petrous part, lacerum part, cavernous part, clinoid part, supraclinoid part, and, communicating terminal part(Bouthillier et al. 1996, pp. 425–433) , which illustrated on Figure 2.7.

Figure 2.7: ICA Parts



Source: This figure was taken from (DePowell et .al. 2014)

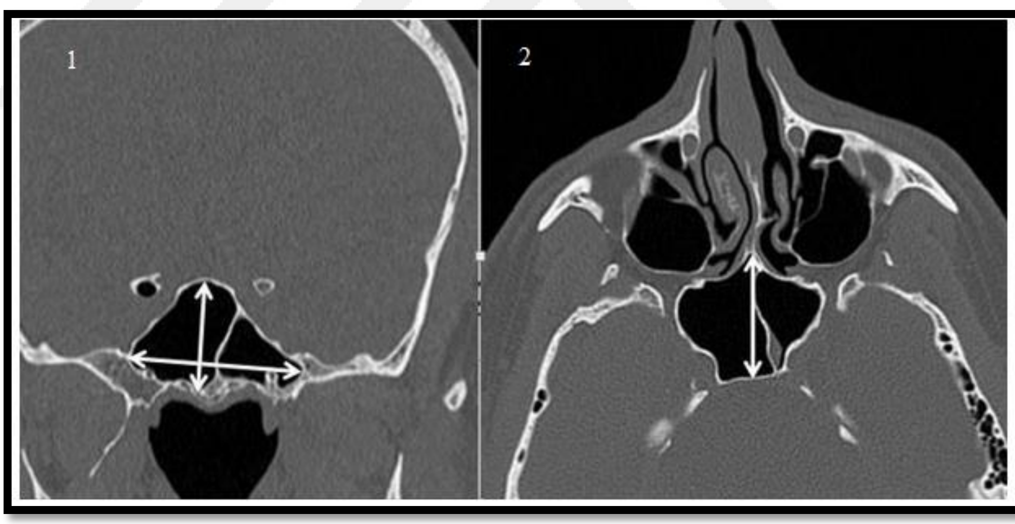
2.6 THE SPHENOID SINUSES ANATOMICAL VARIATIONS

2.6.1 Sphenoid Sinus Volume

Various extension of the sphenoid sinus brings it in varies volume, the sinus volume varies from person to person as well as from both sides, according to insertion site of sinus septum.

The sinus volume had been calculated by changed ways; some reports had an injection of chemical substance into sinus cavity of cadaveric specimens in order to measure the volume. This technique is difficult to be applied on living objects. In recent times, the sphenoid sinus volume is measured by calculating the height, length and width measurements on CT scan check cuts (Figure 2.8). And it found to be from seven to six cubic centimeters (Selcuk et al.2015, pp. 1059–64).

Figure2.8: Illustrations of Sphenoid sinus volume measurements on brain CT



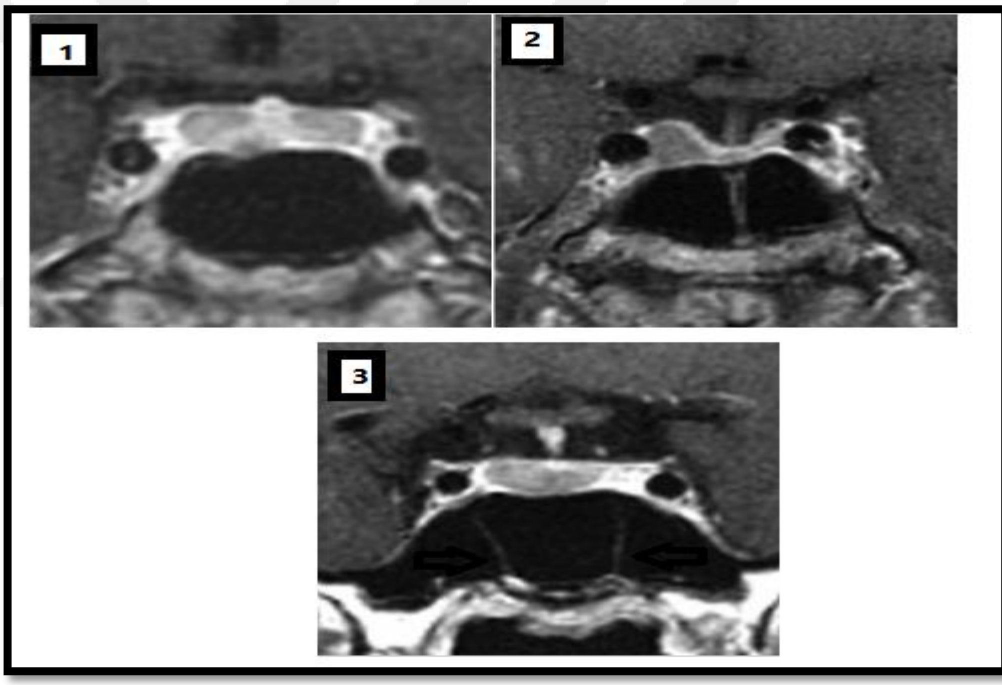
CT Computed tomography:
1: Coronal plane
2: axial plane
Source: This figure was taken from(Selcuk et al.2015, pp. 1059–64)

2.6.2 Septation Of The Sphenoid Sinus

The cavity of sphenoid sinuses is divided into two compartments by an inter-sphenoidal septum and more than one septum can be present dividing the sinuses to multiple compartments (Figure 2.9). The variation in the number of the septum besides insertion to the encompassing structures as the ICA, ON, and cavernous sinus is common among population (Kashyap et al. 2017, pp. 955–959).

Post-surgical morbidity of trans-septal sphenoidectomy can be avoided by preoperative understanding of septal variations as the possible merciless damage to the surrounding neurovascular structures such as ICA and ON take place throughout sphenoid sinus septal dismemberment (Akgül et al. 2016, pp. 4321–4328).

Figure 2.9: Shows sphenoid septae on coronal MRI plane



MRI: Magnetic resonance imaging
1: A septate sphenoid sinus
2: Single septate sphenoid sinus
3: Sphenoid sinus with two septa (arrows point to septa) Zada
Source: This figure taken from (Zada et al. 2011, pp. 1319-1330)

2.6.3 Pneumatization

Pneumatization defined as the existence of holes filled with air within the developed bones, these cavities have a lining epithelial cells (Singh et al. 2017, pp. 78–81) . After birth the marrow of sphenoid bone comprises a red erythropoietic cells and is lacking of air. By the age of seven months up to two years, the Alteration of marrow from red to fatty yellow is assumed to occur (Aoki et al. 1989, pp. 373–375). As the bone marrow changes extend backward reach the basisphenoid plate. Bone marrow aeration continues in a downward and posterolateral direction. The sinus achieves its mature volume by the age of fourteen years. Sphenoid sinuses degree of pneumatization is significantly variable between individuals. As the cavitation of sphenoid bone is asymmetrical, the morphology and volume of the sinus depend on the degree of pneumatization (Locatelli et. al. 2017, pp. 173–179).

Different categorization had been used by different authors to classify sphenoid sinus pneumatization. In general pneumatization can be classified into three categories ;conchal, presellar and sellar .Additional type was included in the classification termed postsellar, in this type the aeration of the sinus spread out to reach the sella turcica posteriorly (Baldea and Sandu 2012).

The sort of pneumatization classification was done by drawing double imaginary upright lines, the first line takes place at the sellar tuberculum anterior to the sella turcica. The second one at the posterior clinoid process(Dias, Albernaz and Yamashida, 2004).

A classification by Hammer and Rådberg (1961, pp. 401–422) classify the pneumatization of sphenoid sinus into 5types (Ramalho et al. 2017, pp. 162–167). Different pneumatization types are illustrated in the Figure 2.10.

i. A pneumatized.

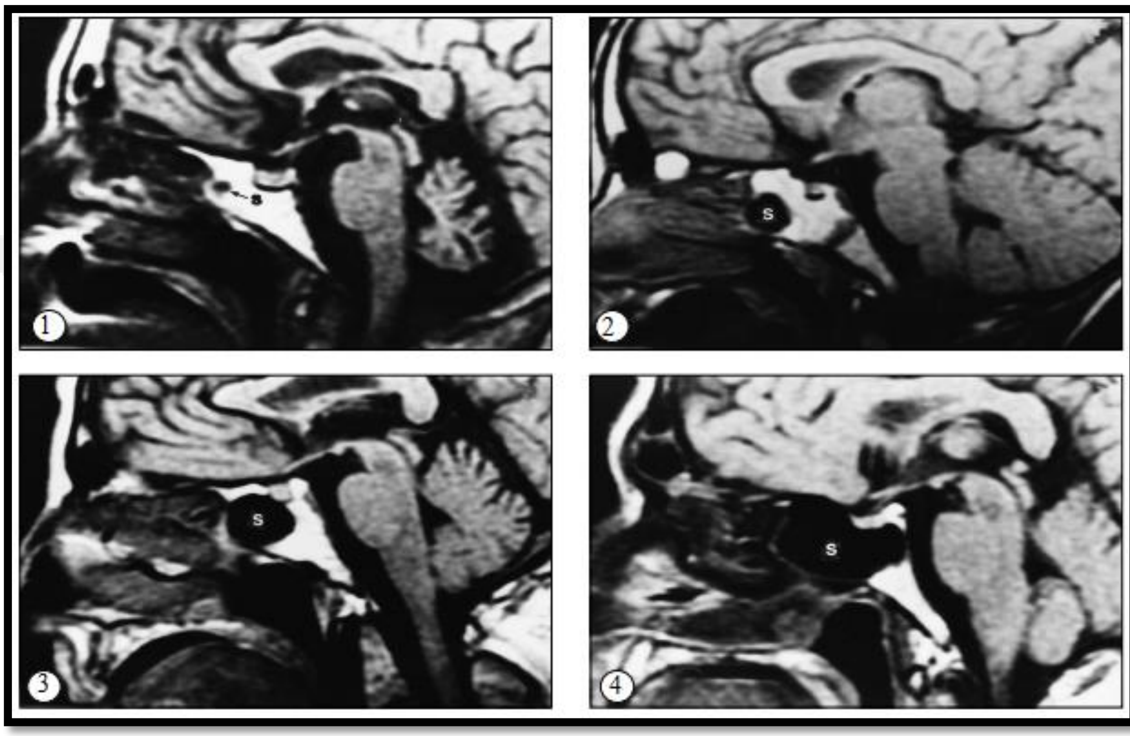
ii. Conchal type: were the pneumatization is minimal and not reach the sella turcica.

iii. Pre-sellar type: here the pneumatization that does not extend beyond the vertical line at the sellar tubercle(Ramalho et al. (2017, pp. 162–167), Dias, Albernaz and Yamashida 2004).

iv. Sellar type : the pneumatization expands after the sellar tubercle line but not extend the vertical line at the posterior clinoid process (Ramalho et al. (2017, pp. 162–167) , Dias, Albernaz and Yamashida 2004).

vi. Post-sellar type : defined as the expansion of pneumatization is beyond the sella turcica (Ramalho et al. 2017, pp. 162–167).

Figure2.10: Pneumatization types of sphenoid sinus on MRI



MRI: Magnetic resonance imaging
1:conchal
2: presellar
3: sellar
4: postsellar
Source: This figure was taken from (Kayalioglu et. al. 2005)

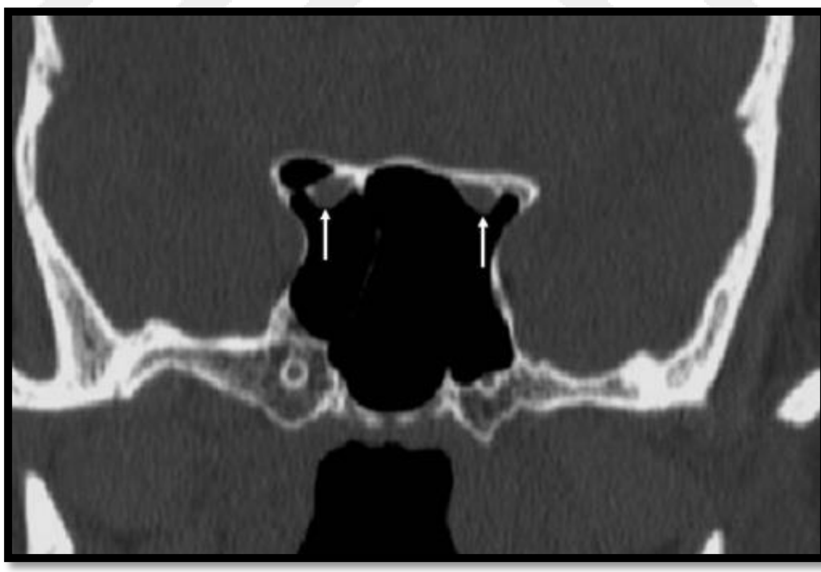
2.6.4 Variation in Optic Nerve and ICA Protrusions

There are two indentations on the lateral wall of the sinus are of significant clinical importance produced by the optic nerve and internal carotid artery. Differing on degree of pneumatization, these two indentations may be hardly noticeable or very obvious, during ETSS it is important to keep in mide that the optic canal and the bulge of the internal carotid artery may only be covered by a very thin and occasionally fragmented bony layer in the area of the sphenoid and that these two vital structures may not be well protected. Besides, Smaller sinus volume and short distances inter optic nerves and inter carotid arteries distances, entry to the suprasellar area is more limited and, as a result more complicated.

The second cranial nerve (ON) located at different positions consequently to degree of sinus pneumatization. Widespread of pneumatization of the sinus possibly will create protuberance of the ON into the sinus as seen in Figure 2.11 below .In some cases it becomes hardly detected and this increase the substantial hazard of damage (Heskova et al. 2009, pp. 149–152).

The optic canal placed in area where the amount of circulation is small. Thus, ON ischemia might be happen at slightly pressure on the nerve. Therefore, the risk of visual loss is raised. Also, the sinus problems such as inflammation or mucocele can affect the vision (Mamatha et al. 2010, pp. 121–124).

Figure2.11: Coronal plane brain CT scan showing bilateral ON protrusion



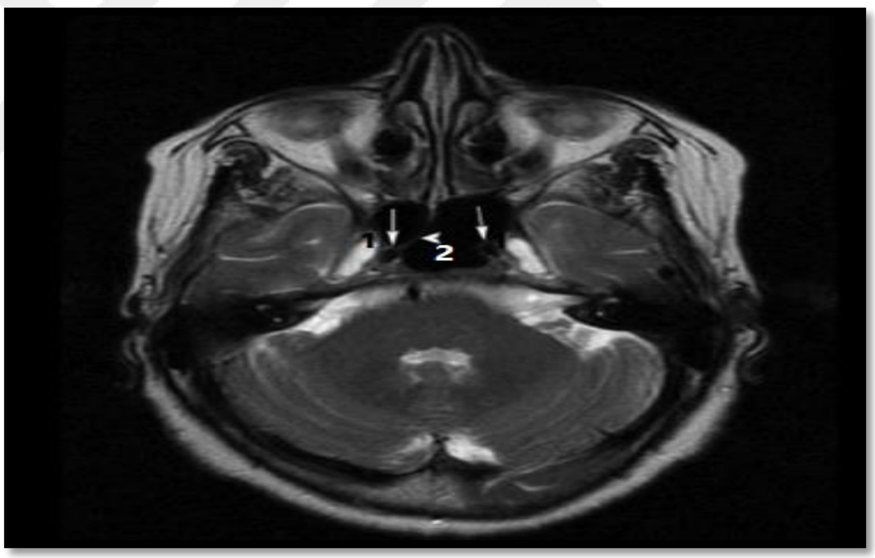
ON: Optic verve(arrows)
Source: This figure was taken from(Reddy et al. 2012)

Moreover, the internal carotid artery is located medially in the cavernous sinus During surgical procedures , the cavernous part is at the greatest risk of damage (Ramalho et al.

2017, pp. 162–167) . The distance between cavernous internal carotid arteries is around 13 mm. (Farımaz et al. 2019, pp. 54–62). Furthermore, decrease in distance between two carotid arteries increase the risk of ICA damage. AS the internal carotid arteries at tuberculum sella is relatively fixed. That makes it at higher risk of surgical trauma.

Detailed evaluation of internal carotid artery protrusions in to the SS before trans sphenoidal approaches is mandatory (Baskin et al. 2003, pp. 168–172). A fatal blood loss can consequence the accidental surgical injury of the ICA within the SS (Mamatha et al . 2010, pp. 121–124). Figure 2.12 showing ICA protrusion.

Figure 2.12: Show ICA protrusion in to sphenoid sinus axial magnetic resonance imaging



Arrow1: Internal carotid artery
Aarrow2: sinoseptum attaches to right ICA.
Source: This figure was taken from (Hatipoglu et al. 2009, pp. 1331–1337)

2.7 ANATOMIC VARIANT OF SPHENOID SINU AND SURGICAL IMPLICANT

The knowledge of anatomy and normal variants of sphenoid sinus is a necessary requisite for the understanding of pathological processes in radiology. As the SS has wide range of anatomical variations between individuals, carful study of these variation is needed prior endoscopic transsphenoidal surgery (ETSS). Expansion of the sphenoid sinus pneumatization can influence the position of related neurovascular structures and become exposed to damage(ELKammash et al. 2014).

Occasionally, the neurovascular structures are exposed within the sinus cavity and connected to the sinus walls by bony stalks(Liu et al . 2013).In conchal pneumatization the bone edge is thicker considered as relative contraindications to transsphenoidal endoscopic skull base surgery(Song et al. 2015). The sellar pneumatization is the most frequent variant in which the aeration is spreads to the sella backward and downward. This result in thinned posterior edge of the clivus and become more vulnerable to trauma. In addition , ON and ICA protrusions become higher with more pneumatization(Güldner et .al. 2012). Therefore, carful recognition of pneumatization types is essential preoperatively.

Intrasinus septae attaching to bony walls of the internal carotid artery and optic nerve need preoperative identification because excessive traction on these septae may lead to an avulsion of the bony walls and catastrophic complications, like carotid artery injury and blindness.

Finally, persistence of the lateral craniopharyngeal canal in association with extensive sphenoid pneumatization and raised intracranial pressure may lead to formation of a spontaneous lateral sphenoid meningoencephalocele and resultant CSF leak. In approximately 80percent of cases of anterior clinoid process pneumatization, the optic nerve is dehiscent into the superolateral aspect of the sphenoid sinus.

2.8. A MAGNETIC RESONANNE IMAGE(MRI)

The paranasal sinuses have been screened by different imaging techniques. Although the paranasal computed tomography is being the best technique for assessment of paranasal sinuses prior to ETSS, MRI scan gives a much better image of the pituitary gland and surrounding soft tissue structures, than other types of scans.

MR has excelled in the examination of soft tissue masses of the paranasal sinuses and nasal cavity, not only in sensitivity, but in specificity. Likewise, MR has improved the diagnostic precision for differentiating neoplasms from inflammatory diseases. This improved distinction is mainly due to the both of the superior soft tissue contrast of MRI and the broadly disparate T2-relaxation values between the neoplasms (high cellular) and inflammatory or infectious processes (high fluid) in this anatomic area. MR's expanding role as the primary imaging modality for clinical problems in the sinonasal region will accompany the decrease in exam time and increase in spatial resolution. (Boll et al. 2002, pp. A7-6, Hasso and Lambert 1994, PP.209-223). Besides, magnetic resonance imaging has a critical role in the evaluation of optic nerve and the complete visual pathway(Daniels et al. 1984, pp. 79–83). Therefore, MRI is important method for evaluation of the patients preoperatively to minimize serious complication (Carrau et al, pp. 914–918).

MRI gives consistent knowledge about differences of sphenoid sinus anatomy. Additionally, it makes it achievable to differentiate the cavernous sinus from internal carotid artery (ICA). This knowledge benefit is avoidance intra-operative ICA injury throughout ETSS.

2.9 TRANSSPHENOIDAL ENDOSCOPIC APPROACH

Endoscopic transsphenoidal sinus surgery (ETSS) is a minimal invasive procedure used in management of pituitary tumors(Carrau et al .1996).Nowadays, it is use extends to manage cranial base lesions and most of sellar lesions.

Even though, it can cause a serious complication. Therefore, good assessment is necessary demands preoperatively in order to diminish sever injury of the surrounding structures.

Previously the target of the endoscopic sinus approach was to exchange the open surgery to treat chronic sinus infection. This attained by opening of the blocked sinus drainage (Lanza & Kennedy1992, pp. 505–511). Studies reported the effectives of functional endoscopic sinus surgery in the management of the repeated sinus infection, post-surgery symptoms improvement and improved quality of life in more than 75percent of cases (O'Brien , Hamelin, and Weitzel 2016, pp.10-21).

The ETSS developed to be used in sinus tumor and even skull base tumors (Snyderman et .al. 2008, pp. 658–664), the key principles of endonasal skull base surgery are choosing a surgical corridor that minimizes the need for neural and vascular manipulation, cerebrospinal fluid leak(Mattox Kennedy et al. 1990, pp. 857–862), endoscopic orbital decompression (Kennedy et al. 1990, pp. 275–282).

2.10 ETSS COMPLICATION

As with any surgical procedure, endoscopic sinus surgery has associated risks. Although the chance of a complication occurring is very small, fatal complication can be occurred.

2.10.1 Bleeding

Most sinus surgery involves some degree of blood loss, which is generally well tolerated by the patient. However, on occasion, significant bleeding may occur from accidental surgical trauma of the ICA that can result in a massive blood loos and the mortality rates about 40percent(Perry et al. 1980, p.74).

The prevalence of ICA trauma during ETSS is reduced to 1.3-3.9 percent. Whereas, the ICA injury frequency in open old-style skull operations rate is more than 3-8percent(Weidenbecher et al. 2005, PP.640-645).The reported injury less frequently on the right ICA (ratio 1.3:1) (Chin et al. 2016, pp. 582–590).

The ICA can be injured along its different segments (C1–C7). The majority of reported ICA injuries have occurred in the cavernous segment(Duek et al. 2017, pp. e125–e128). Recent advances in endoscopic endonasal approaches have allowed for greater exposure of the ventral skull base and thus more portions of the ICA can potentially be injured, similarly the expansion of endoscopic techniques to comprise exposure to areas such as the clival area have amplified the risks of petrous injuries.

1.10.2 Ocular Complications

Ocular problem that occur during ETSS forms 16percent to 50percent of all complications, Visual loss is one of the devastating complications of FESS has been reported after sinus surgery due to injury to the eye or optic nerve during sphenoidal septum dissection (Clemens et al. 1992, pp. 81–84), additional orbital complications after FESS including retro bulbar haemorrhage, and orbital ecchymoses from ICA injury, damage to the eye muscles may result in double vision from direct injury to the muscle throughout the sinus surgery with the operational tools, and Persistent tearing of the eye from nasolacrimal drainage system injury, and proptosis all are reported(Al-Mujaini et. al. 2009, p.70).

2.10.3 Intracranial complications

Since the sinuses are located nearby the brain, there is an occasional chance of creating a leak of spinal fluid or injuring the brain, Intracranial hemorrhage, and Dural damage which may create a potential pathway for, Meningeal infection, and Brain abcess (Zweig et al. (2000, pp. 195–201 , Schnipper and Spiegel 2004, pp. 453–472).

Other uncommon risks of surgery include alteration of sense of smell or taste; persistence or worsening of sinus symptoms and facial pain(De Corso et al. 2018, pp. 485); change in the resonance or quality of the voice(Kim et al. 2013, pp. 67–70).

2.11 PREVELANCE OF SPHENOID SINUS VARIATIONS ACCORDING TO THE PREVIOUS STUDIES

Numerous investigates were directed on sphenoid sinus variations among different population using altered methods either imaging, cadaver, or macerated bones. They were used also different classification and different sample sizes.

2.11.1 Previous Studies On Sphenoid Sinus Volume

A study was done by Yonetsu et al. (2000, pp. 453–472) investigated the relation between age and expansion and reduction in pneumatization of the sphenoid sinus among 214 Japanese patients age ranged from 1 to 80 years examined by helical CT scan. They stated the pneumatization started at 5 years old. As well, they noticed reduction in the sinus volume by the age of 70 years to 71percent of its maximum volume(Yonetsu et al. 2000, pp. 453–472).

Furthermore, A research by Oliveira et al. (2009, pp. 390–393) studied the exactness of human, sphenoid sinus volume variation and relation with sexual dimorphism using 3D-CT scan in axial and coronal sections amongst USA population. The reported mean sphenoid sinus volume in this study was 13.6cc, minimum volume 3.3cc, and maximum volume 24.25cc. Also, there is significant difference in the volume between genders. The mean volume for male was 15.4cc and mean female volume was 10 cc(Oliveira et al. 2009, pp. 390–393).Similarly, Li et al.(2014, p.2) studied the association of the sphenoid sinus volume and protrusion into the sinus amongst 350 Chinese patients examined by high resolution CT scan, aged from 25-65 years. They reported the mean volume of the sphenoid sinus was 14.3 cc. Beside this they also devoted ICA relation prevalence to the sinus as 29percent protruded ICA, and dehiscent ICA wall 2.3percent(Li et al. 2014, p.2).

Moreover, Selcuk et al. (2015) assessed the relationships of paranasal sinus volumes and different climates using PNS CT scan for 155 patients from different city center aged from 27 to 63 years. They reported mean volume of the sphenoid sinus was 7.81cc (Selcuk et al. 2015, pp.1059-1064).

In a similar way, Cohen et al. (2017, pp. 96–102) had investigated the volumes of the maxillary, frontal and sphenoid sinus using CT scan in two different age groups one aged from 25-65years and the other from 65 years and above. They reported significant decrease in the mean volume of the sphenoid sinus from 4.84 cc in first group to 3.84 cc in older age group. In addition, sphenoid sinus volume was significantly larger in male (4.7 cc) than female (3.55 cc)(Cohen et al. 2018, pp. 96–102).

Sphenoid sinus volume had been measured using different methods (Cohen et al. (2017), and Li et al. (2014), Oliveira et al. (2009), Yonetsu et al. (2000)), different Software was used to calculate sphenoid sinus in three-dimension images. Whereas, (Li et al. (2014), Selcuk et al. (2015)) calculated the volume by measuring the three dimensions of the sphenoid sinus in plane images.

2.11.2 Previous Studies On Sphenoid Sinus Septa

A research on sphenoid sinus septation was done by Kapur et al.(2012), among 200 Bosnia patients using CT scan and reported the frequency of aseptate sinus 2percent, single septum 32percent, more than one septum in 32percent, four septa were reported in 4.8percent (Kapur et al.2012).

Moreover, Kashyap (2017, pp. 955-9) and his colleagues had reported variation of the sphenoidal sinus septum among Indian population, 80 patients aged from 14 to 80 years examined by PNS CT scan. They reported the frequencies of single septate sinus 67percent, two septate sinus 21percent, three septa 6.25percent, aseptate sinus 5percent. While the attachment sites were to ICA 35percent, sella 26percent, lateral sinus wall 12percent, ON2.5percent, sella and ICA 11.25percent, and lateral wall and ICA 6.25percent (Kashyap et. al. 2017, pp. 955-9).

2.11.3 Previous Studies on Sphenoid Sinus Pneumatization

A research paper done by (Kayalioglu et al. 2005, pp.79-84) assessed the sphenoid sinus pneumatization variations among Turkish population using magnetic resonance images, bones, and cadaveric heads. They reported the frequency of the pneumatization types; (1.9percent) conchal type which noticed only in female, presellar type 9percent (5.6percent male and 2.8percent female), sellar type 52percent (24.4percent male and 23.9percent female), and post sellar type 36.4percent (22.2percent male and 19.5percent female) (Kayalioglu et al. 2005, pp.79-84).

Similarly, Battal et al. (2014, pp.232-237) studied the relationship between the variations of the sphenoid sinus and nasal septum in Turkish population from 18-89 years old by using computed tomography angiography scan of the head and neck. They reported the frequency of postsellar type 68percent, presellar type18.2percent, sellar type 12.7percent, conchal 1percent (Battal et al.2014, pp.232-237).

In contrary, Sevinc et al. (2014, pp.1140-1143) had studied the normal variation of sphenoid sinus pneumatization among Turkish population using MRI. They had followed classification of pneumatization of the sphenoid sinus into three types (conchal, presellar, sellar) and observed prevalence of conchal type 0.5percent,16.6percent presellar, and 83percent sellar type (Sevinc et al. 2014, pp.1140-1143).

A study done by Hindi et al. (2014, pp.429-463). and his colleagues to evaluate the pneumatization of all paranasal sinuses using PNS CT scan among Malaysian population in Kuala lumper. Patients were aged from 18-89 years. Also, They had classified pneumatization of the sphenoid sinus into three types (postsellar, presellar, conchal) and observed prevalence of postsellar type (83.3percent), presellar type 16.7percent, and conchal type had not seen in this study(Hindi et al. 2014, pp.429-463).

Similarly, Veazi et al. (2015) who had studied the three types classification of the sphenoid sinuses pneumatization (conchal, presellar, and sellar) among American population using high contrasted CT scan of the brain and reported the frequencies of conchal type 2.5percent, presellar type 23.8percent, and sellar type 73percent(Vaezi et al. 2015).

One more research paper for Anusha et al. (2015, pp.1183-1190) studied the sphenoid sinus variations and important land marks using brain CT scan and PNS CT scan in Malaysia. The sphenoid sinus pneumatization in this study classified into three types (conchal, presellar, and sellar) and their frequencies were 0.3percent for conchal type, 6.5percent for presellar type, and 93percent sellar type.(Anusha et al. 2015, pp.1183-1190)

On the contrary, Rahmati et al. (2016, p.32) had analyzed the normal anatomical variations of the sphenoid sinus using cone beam CT scan among Iranian population. They found the frequency of the pneumatization types 83percent post sellar type, 14.6percent sellar type, 1.9percent presellar, and no conchal type had seen(Rahmati et al. 2016, p.32).

Besides, Gibelli et al. (2108, pp.193-198) studied the anatomical variants of sphenoid sinus pneumatization among North Italian population using brain CT scan for 300 patients aged from 25-99 years old. They elaborated the frequency of the sellar type 77.3percent, postsellar type 14.7percent, presellar type 8percent (Gibelli et al. 2018, pp.193–198).

2.11.4 Previous Studies on Relation of The Sphenoid Sinus to The Optic Nerve And ICA

A research conducted by Sirikci et al. (2000, pp. 844–848) studied the anatomical variation of the sphenoid sinus and nearby neurovascular structures among 92 European population using paranasal CT scan and reported prevalence were 31.5percentpercent for protruded optic nerve. While ICA protrusion frequency was 26.1percent (Şirikci et al. 2000, pp. 844–848).

Another study done by Heskova et al. (2009) analyzed the relation of the optic nerve to the posterior ethmoid and sphenoid sinuses using CT scan among Slovakia population. 34 computed tomography for 18-74 years old patients examined and the prevalence of the optic nerve protrusion was 35.5percent(Heskova et al. 2009, pp. 149–152).

On the same extends, Mamatha et al. (2010) has reviewed the SS variations and their influence on the enclosed structures among 20 CT scans of Indian patients aged from 16 to 54 years. They informed the prevalence of optic nerve protrusion 65percent, and the prevalence ICA protrusion 50percent(Mamatha et al. 2010, pp. 121–124).

The same, Fasunla et al. (2012, pp. 57–64) studied the anatomical variation of the sphenoid sinus and nearby neurovascular structures among Nigerian population using CT scan and reported prevalence were 38.2percent for protruded optic nerve, whereas ICA protrusion frequency was 27.35(Fasunla et al. 2012, pp. 57–64).

2.11.5 Previous Studies on Inter Optic Nerve and Inter ICA distance

A study conducted by Bergland et al(.1968, pp. 93–99)examined 225 human autopsy, they reported smallest interoptic nerve distance at the level of optic foramen was of 13 mm, differing from 8 to 20 mm (Bergland etal .1968, pp. 93–99).

Similarly, a research was made on 20 cadaveric samplings by Slavin et al.(1994 pp. 136–144), they measured the interoptic nerve distance as the distance between centers of ONs, it was ranged from 18to23mm, at the level of Intracranial Opening of the Optic Canal (Slavin et al. 1994, pp. 136–144). The same, study was done by Jho & Ha(2004, pp. 1-8), Six cadaver head specimens were studied , The reported interoptic nerve distance at the intracranial opening of the optic canal was 18 mm (varying between 15 and 22 mm),(Jho and Ha 2004, pp. 1–8).

Moreover, an analysis was done on 15 human cadaver heads specimens by Cavallo et al. (2007, p. ONS-24) and his colleagues, they measured distance between the two carotid prominences in the sphenoid sinus is the zone just beneath the tuberculum sellae. The mean Intercarotid distance at the tuberculum sellae was 14 mm, ranging remarkably from 9 to 24 mm (24) (Cavallo et al. 2007, p. ONS-24).

On the same extends, another study done by Yilmazlar et al.(2008, pp. 165–174), analyzed Eighty-five sellar and parasellar tissue specimens fixed on formaldehyde taken from human cadaver, MRI scans of 28 macroadenoma patients and 22 healthy adults also were evaluated in this study, In cadaveric specimens, the reported intercarotid artery distances (cavernous part) were 17 ± mm anteriorly, 20 ± 4 mm medially, and 19 ± 4.6 mm posteriorly. Whereas in normal-sella images, the distances were 15.4 ± 2 mm anteriorly, 16 ± 3 mm medially, 16 ± 3.4 mm posteriorly(Yilmazlar et al. 2008, pp. 165–174).In the same way, the intercarotid distance measured by Hamid et al. (2008, pp. 9–15), using coronal MRI scan was 23mm(range12-30mm) (Hamid et al. 2008, pp. 9–15) .

Additionally, a research paper done by Mascarella et al.(2015), measured the distance between different part of internal carotid artery amog 212 patients and 34 controls examined by CT and MRI scan. they found intercarotid distance at cavernous part was17.3mm(16.1-18.5);while the distance between paraclinoid parts was13.3mm(12.7-13.9) in control group(Mascarella et .al. 2015).

Furthermore, a study conducted by Farımaz and his group in 2019, studied the morphometry of the cavernous segment of ICA using 173 CT scan and 49 MRI, the given intercarotid distance at the cavernous part in this study was 13.6 ± 2.8 mm(Farımaz et al.2019, pp. 54–62).

3. DATA AND METHOD

3.1 STUDY STRATEGY

The study is a retrospective assessment of SS and the surrounding neurovascular structure via hypophyseal MRI in the Radiology Department at Bahcesehir University (BAU) Hospital (Medical Park Göztepe) in Istanbul.

3.2 STUDY POPULATION

A patients hypophyseal MRI at Medical Park hospital (goztepe). from period 1st June2015 to 31stJuly2019 were reassessed.

Patients with these criteria are included in our study:

a. Age between 14-70 years. The explanation for getting going with 14 years old, as the sphenoid sinus reach to mature size by the age of 14 years (Scuderi, Harnsberger and Boyer 1993, PP.1101-1104) . Whereas the restriction of patients age to 70 years based on evidence that the volume of the sphenoid sinus decreases as well as the pneumatization of the SS by the age of 70 years old (Yonetsu et al. 2000, pp. 453–472).
b. Negative history of previous surgery in paranasal sinuses, or in sellar area.
c. Negative history of tumour in sellar area.
d. Negative history of fracture of the cranio-facial bones.

3.3 SAMPLE SIZE

The population of the study consists of patients with pituitary MRI records of the Medical Park Göztepe Hospital. The oldest hospital records are until June 2015. Without sample selection, all enrolled patients that meet the inclusion criteria of our study were planned to be included in the study. Thus, a total of 204 patients was included in the study. After the analysis of the study was completed, the power of the study was calculated post-hoc.

3.4 MATERIAL AND DATA GATHERING PLAN

Coronal T2-weighted and Sagittal T1- weighted and T2- weighted hypophyseal Magnetic Resonance Images (MRIs) with 2 mm thickness sections were retrieved. The images were converted in to digital by imaging Picture archiving and communication systems (PACS) format.

3.5 DATA GATHERING

After obtaining the approval from the Clinical Research Ethics Committee, data were collected. A Pituitary imaging scans were performed at the Bahcesehir University Hospital (Medical Park Göztepe) using 3 Tesla Philips Achieva running system. And the images were retrieved using Synapse PACS (Picture Archiving and Communication System) from FUJIFILM medical imaging and information management system.

The copies of patient's MR images fulfilled the inclusion criteria were reviewed in the Radiology department revised in coronal and sagittal planes.

Measurement of SS volume, and evaluation of the septation, its number, and insertion site, were investigated.

As well as, assessment of the types of pneumatization of the sphenoid sinuses were done according to a pneumatization; conchal; presellar; sellar; and post sellar type.

Finally, assessment of the optic nerve and internal carotid artery protrusion in the sinus and measurement of inter optic nerve, and inter carotid artery distance were carried out. The gathered data were organized in charts tables and bar graph.

3.6 TEACHING SESSIONS

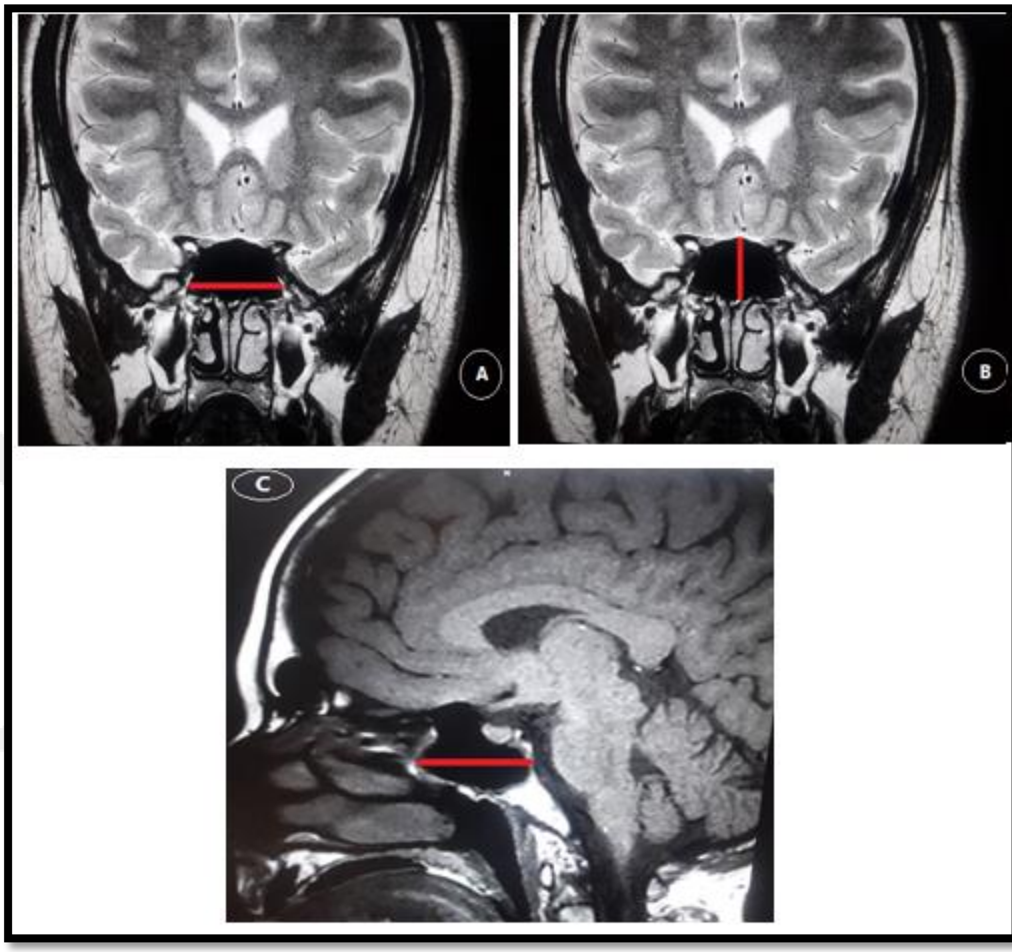
Teaching was entrusted by two senior radiologists at the Radiology Department for reassessment of the MR images, valuation of the various sphenoid anatomical landmarks and the measurements way.

3.7 PERFORMING MEASURMENT

The MRI of the pituitary gland of 204 patients aged from 14-70 years were reviewed on a computer using Synapse PACS software. This software provides three planes for the images, contrast enhancement image, and the images of 2 mm thickness slices reconstructed in coronal and sagittal planes. Using the windowing technique to enhance the contrast of soft tissue and bone of the skull.

The volume of the sphenoid sinus was measured on the tow-millimeter thickness image using bone windowing technique in coronal T2-wigheted and sagittal T1- weighted planes. The measurements were pointed at the longest dimension’s width, height and depth as shown in figure 3.1. The volume calculated using the formula a×b×c and expressed in cubic centimeters (Selcuk et al. 2015).

Figure 3.1: Illustrating the MRI measurement of sphenoid sinus



A: width on coronal T2-weighted plane(red line)
B: height in coronal T2-weighted plane(red line)
C: depth in sagittal T1-weighted plane (red line)
Source: This figure adopted from BAU hospital records and prepared by Fatma Alfageih

The assessment of the septation and emphasize on the number, insertion site, using the software to adjust the bone window manually to clarify septum in coronal T2- weighted plane. The images were studied to verify the site of attachment, whichever at the sella, lateral wall of the sinus, internal carotid canals, or optic nerve canals.

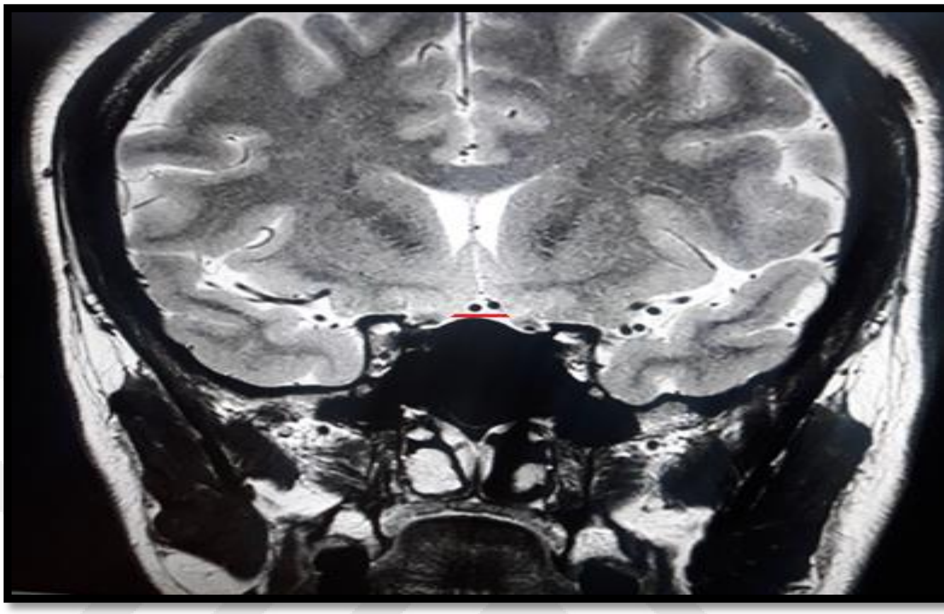
The types of the sphenoid sinuses pneumatization were evaluated by viewing MR images in sagittal T1- weighted and T2- weighted plane.

Then aeration of the SS was defined agreeing to Hummer and Radberg classification. Type I is a pneumatization type where there is lack of the aeration of the sinus; Type II is conchal type where the pneumatization is not related to the sella turcica; Type III is the presellar pneumatization type where aeration does not expand after perpendicular line from sellar tubercle; Type IV is sellar type where airspace confined to the sella turcica; Type V is the post sellar type the pneumatization extends further to the perpendicular line drawn from the posterior clinoid process.

Investigation of the optic nerve and ICA protrusion into the sinus relation to the sinus was done by looking for any observed optic nerve protrusion into the sinus and any degree of inward position of ICA into the sphenoid cavity considered as protrusion in coronal T2-weighted plane.

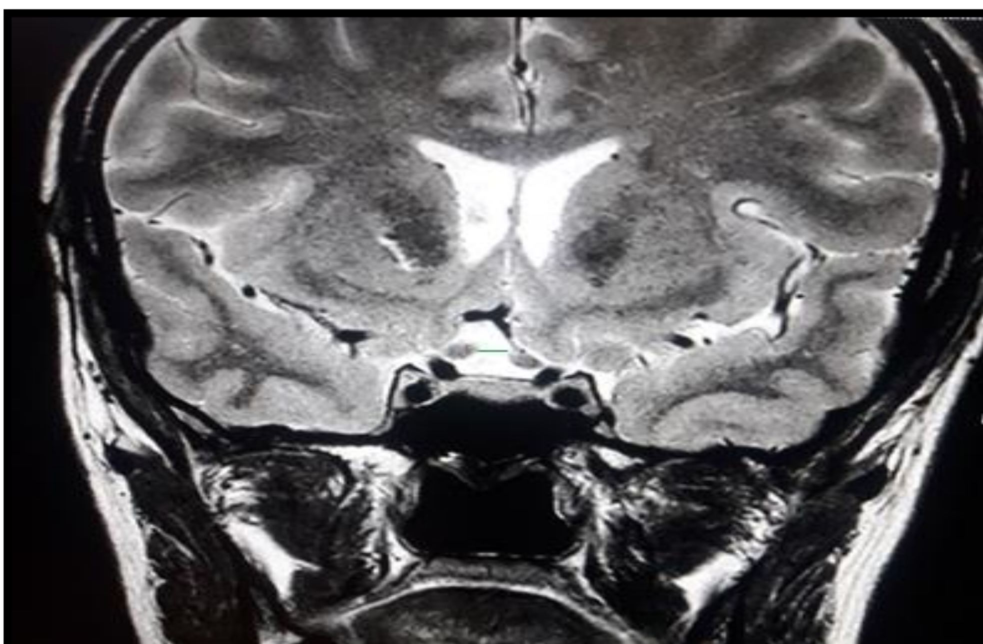
The distance between ON, is considered as the shortest distance between the intracranial parts of ONs, it was taken at two points. The first point just after coming out from optic foramen (IOND1) as shown in Figure 3.2. The second point prechiasmatic suprasellar at which optic nerves lei superior to paraclinoid internal carotid arteries (IOND2) (Figure 3.3). As well as the distance between paraclinoid segments, and the distance between cavernous segments of internal carotid arteries (figure 3.4) was measured manually in millimeter in coronal T2- weighted plane.

Figure 3.2: Illustrates the measurement of IOND1



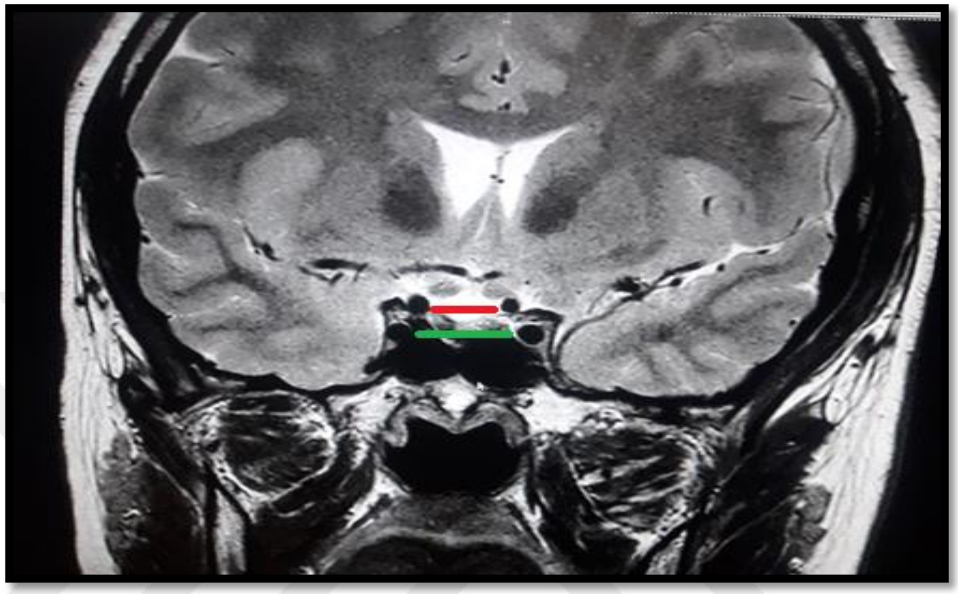
IOND: Inter optic nerve distance (red line)
Source: This figure adopted from BAU hospital records and prepared by Fatma Alfageih

Figure 3.3: Illustrates the measurement of IOND2



IOND: Inter optic nerve distance (green line)
Source: This figure adopted from BAU hospital records and prepared by Fatma Alfageih

Figure 3.4: Illustrates the measurement of inter carotid distance



Red line: the distance between two paraclinoid ICAs
Green line the distance between two cavernous ICAs
Source: This figure adopted from BAU hospital records and prepared by Fatma Alfageih

3.8 STSTISTICAL ANALYSIS OF THE MEASURED PARAMETERS

The collected data were analyzed using Statistical Package for Social Science (SPSS) version 20.0 software, and the continuous variables are expressed in mean (standard deviation) and median, also the categorical data were expressed in frequency. In the same context, the differences between the two categorical variables were examined using chi-square and t-test. Spearman and kruskal wallis correlation tests were used for the correlation of continuous variables. A probability level of less than 0.05 considered is statistically significant.

3.9 CONFIDENTIALITY AND PRIVACY OF THE SAVED DATA

The privacy of the collected data was protected during recruitment for the study as there were no identifiers collected such as the names, telephone number, address. Other data as the age and patient ID were collected in file with only access to approved researchers.

4. FINDING

The whole number of subjects are 204 aged between 14-70 years and the mean age was 34,07±10,88 years, 204 hypophysial MRI were examined, and the gender distribution in the study population was 73 cases are males, and representing 35.8 percent of the samples, while the rest of the cases are 131 females which are representing 64.2 percent of the total sample.

Tables 4.1, 4.2, and Figure4.1 below show the distribution of sample by age and sex.

Table 4.1: Illustrates sex distribution among our study

Sex	Frequency	Percent
Male	73	35.8
Female	131	64.2
Total	204	100.0

Source: This table was prepared by Fatma Alfageih

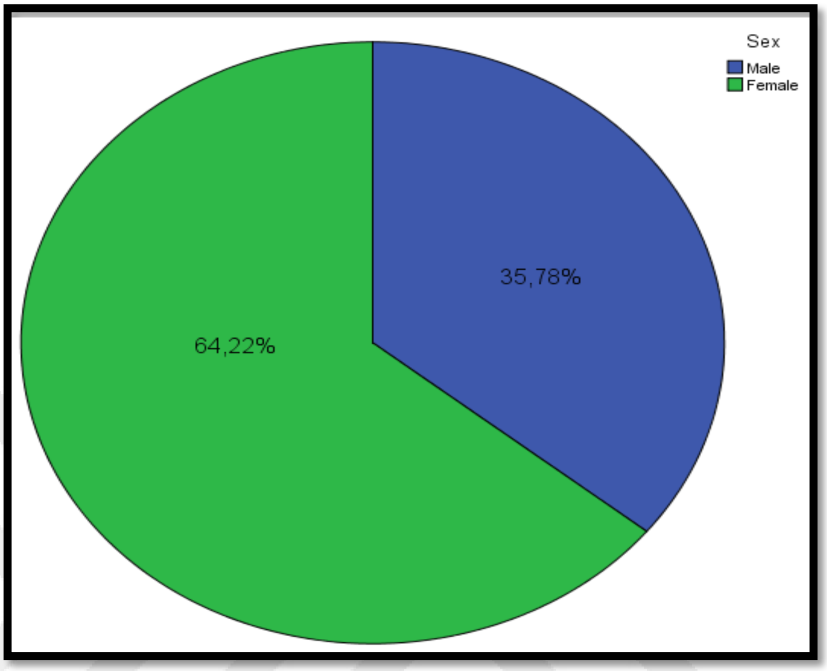
Table 4.2: Illustrates age of patients included in the study

Minimum age	Maximum age	Median age	Mean age	STD
14 Years	68 Years	32.00 Years	34.07 Years	10.88

STD: Standard deviation

Source: This table was prepared by Fatma Alfageih

Figure 4.1: Distribution of gender among study population



Source: This figure was prepared by Fatma Alfageih

4.1 VOLUME OF THE SPHENOID SINUS AMONG STUDY POPULATION

The total volume of the sphenoid sinus calculated by measuring its dimensions. Table 4.3 below illustrates the maximum volume of sphenoid sinus which was 53.56 cubic centimeters(cc). The mean volume was 23,42 ± 8,07 (cc). The minimal calculated volume was 8.4(cc).

Table 4.3: The range of sphenoid sinus volumes

	Minimum	Maximum	Median	Mean	STD
Volume in cubic centimeter	8.4	53.56	22.45	23.42	8.07

STD: Standard deviation
Source: This table was prepared by Fatma Alfageih

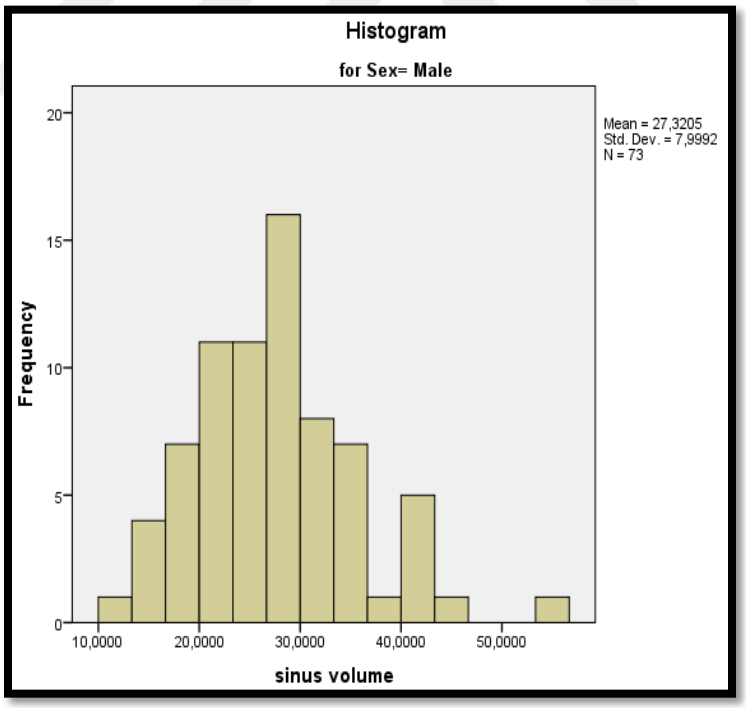
In the Table 4.4, and Figures 4.2,4.3 below show that there was a significant variation in the volume of the sphenoid sinus between male and female p value =0.000. The mean volume of male sphenoid sinus was 27,32±7.9 cc, while the mean female volume was 21,24 ±7.2 cc.

Table 4.4: Sphenoid sinus volume variation in relation to sex

Sex	Mean Volume (cc)	STD
Male	27.32	7.9
Female	21.24	7.2

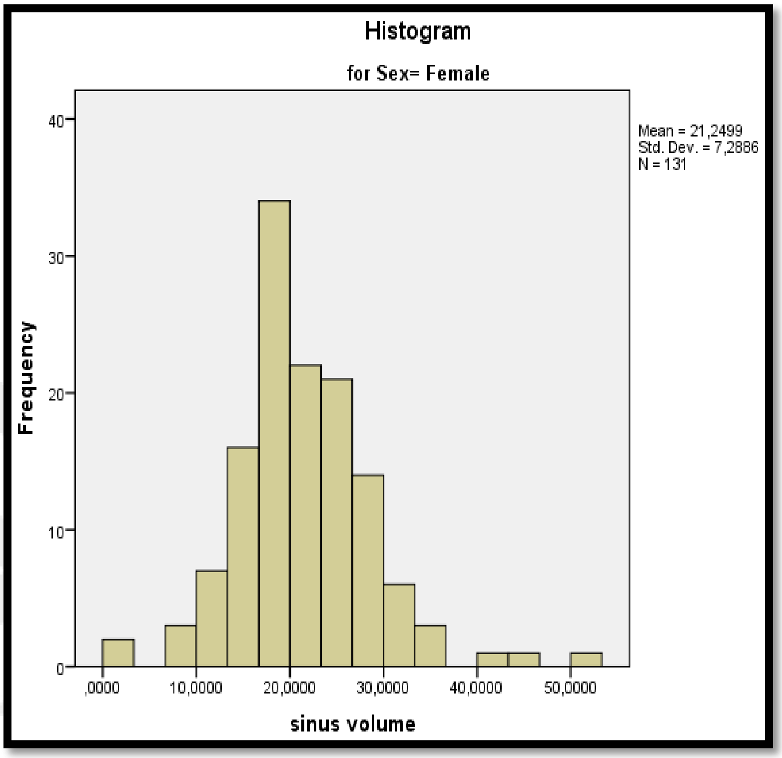
cc: Cubic centimeter
STD: Standard deviation
Source: This table was prepared by Fatma Alfageih

Figure 4.2: Distribution of sinus volume among male



Source: This figure was prepared by Fatma Alfageih

Figure 4.3: Distribution of sinus volume among female



Source: This figure was prepared by Fatma Alfageih

4.2 SPHENOID SINUS SEPTA NUMBER AND THEIR SITE OF ATTACHMENT AMONG STUDY POPULATION

Sphenoid sinus varies in the number of their septa that divide it into compartments. The Table 4.5 and Figure 4.4 below summarize the prevalence of the number of sinus septa variations. In detail, Aseptate sphenoid sinus is seen in 4.4percent of the study population (Figure 4.7). This variant distributed was more in female (5,3percent) than in male (2.7percent). While sphenoid sinus with one septum as showed in Figure 4.8,4.9 was seen in 61.8percent of the study population. In contrast, this variant was found more among male subjects (64.4percent) than in female (60.3percent). Also, this study found 21 .1percent of the study population had sphenoid sinus with two septa.22,1percent of female and 19,2percent of male subjects had two septa (Figure 4.10,4.11). Moreover, three septa sinus accounted for 10.8percent of the study population (Figure 4.12). Among male subjects, 13,7percent had three septa. However, in female subjects it was only 9,2percent. Lastly, four septa sinus was manifested in four patients and account for 2.0percent of the study population, it was seen only in female. Although there was no statistical significance between the number of the septa and the gender, p value =0.38.

Table 4.5: The number of sphenoid sinus septa among study population

Number of Septa	0	1	2	3	4
Frequency	9	126	43	22	4
Percent	4.4%	61.8%	21.1%	10.8%	2.0%

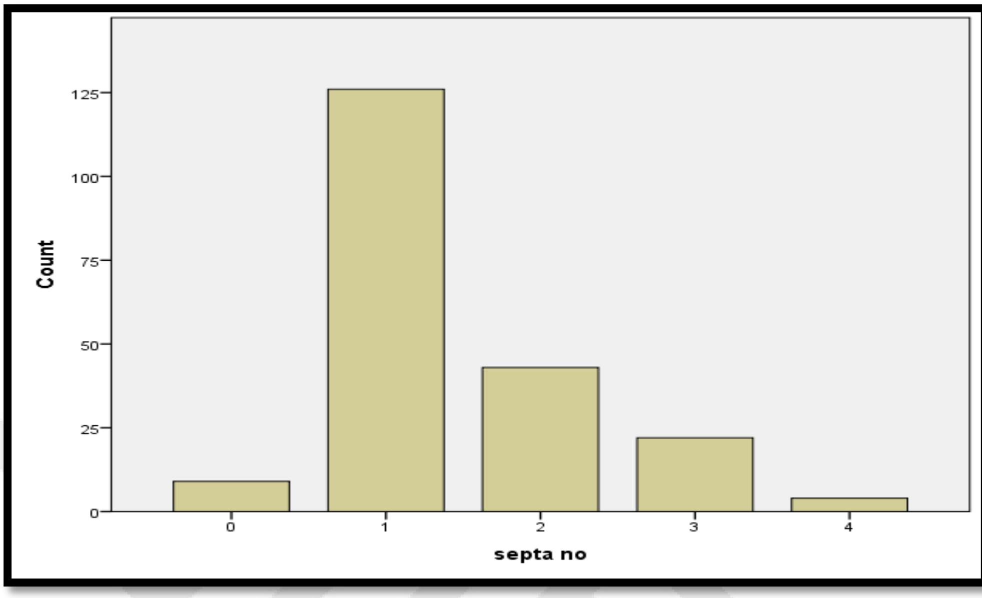
Source: This table was prepared by Fatma Alfageih

Table 4.6: The number of sphenoid sinus septa in relation to sex

Sex	Septa Number				
	0	1	2	3	4
Male	2(2.7%)	47(64.4%)	14(19.2%)	10(13.7%)	0(0%)
Female	7(5.3%)	79(60.3%)	29(22.1%)	12(9.2%)	4(3.1%)

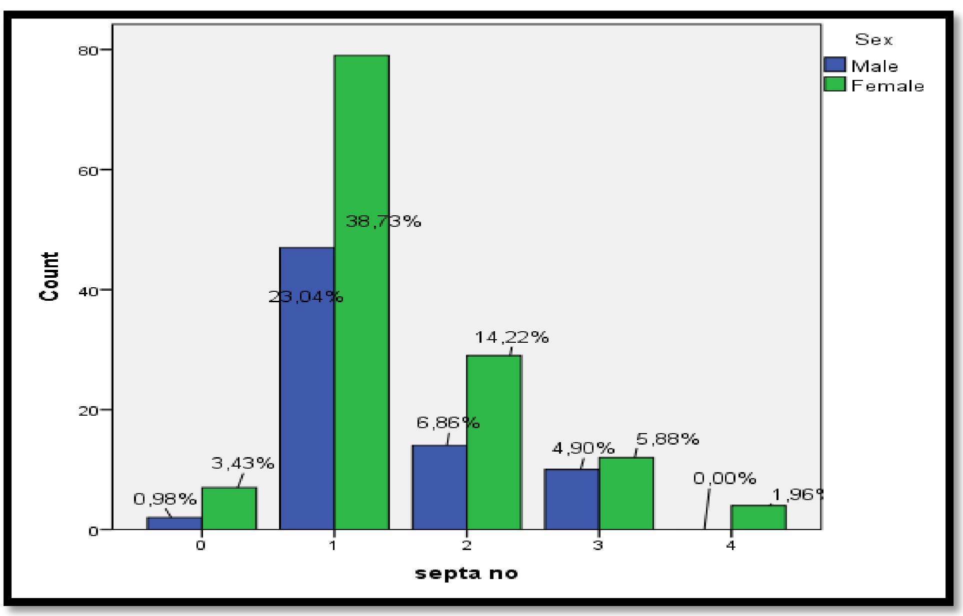
Source: This table was prepared by Fatma Alfageih

Figure 4.4: The Distribution of sphenoid sinus septa among study population



Source: This figure was prepared by Fatma Alfageih

Figure 4.5: Distribution of sphenoid sinus septa between gender



Source: This figure was prepared by Fatma Alfageih

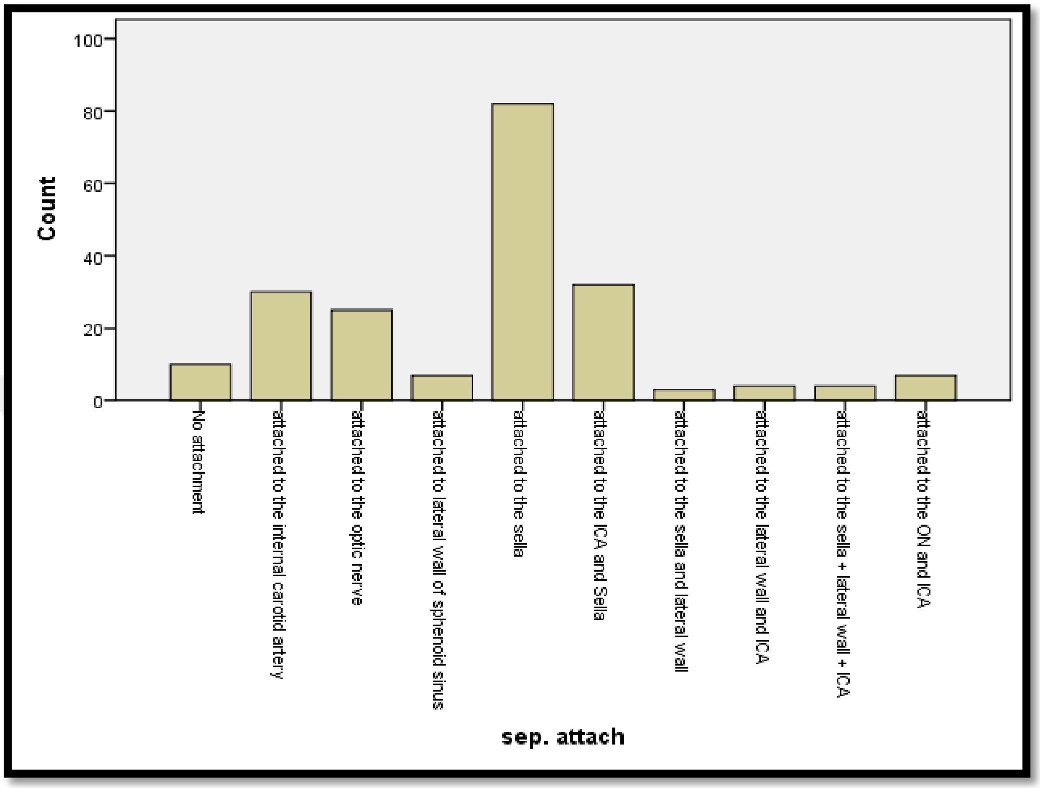
In table 4.7 shows wide range variation of the site of the septum attachments. The sphenoid sinus septum was predominantly attached to the sella turcica 40.2percent (Figure 4.9). Second predominant attachment site of septa was at sella and internal carotid 15.7percent (Figure4.12) and followed by internal carotid artery 14.7percent as shown in Figure4.10. Septa attached to optic nerve were seen in 12.3percent of study population (Figures 4.8). 4.4percent was found with no septa attachement.3.9percent of study population had sphenoid sinus septa attached to lateral wall only. While 3.4percent showed septa attachment to ON and ICA. Besides that, 2percent of study population had septa inserted to the lateral wall, and ICA , and same proportion was found with septa attached to sella, lateral wall and ICA (2percent), The least frequent variation of the septum attachment site was sella and lateral wall which account for 1.5 percent of the study population(Figure 4.11).

Table 4.7: The attachment sites of the sphenoid sinus septa

Variation	Number	Percent
No attachment	9	4.4
Attached to the ICA	30	14.7
Attached to the ON	25	12.3
Attached to the lateral wall	8	3.9
Attached to the sella	82	40.2
Attached to the ICA and Sella	32	15.7
Attached to the sella and lateral wall	3	1.5
Attached to the lateral wall and ICA	4	2
Attached to the sella + lateral wall + ICA	4	2
Attached to the ON and ICA	7	3.4
Total	204	100.0

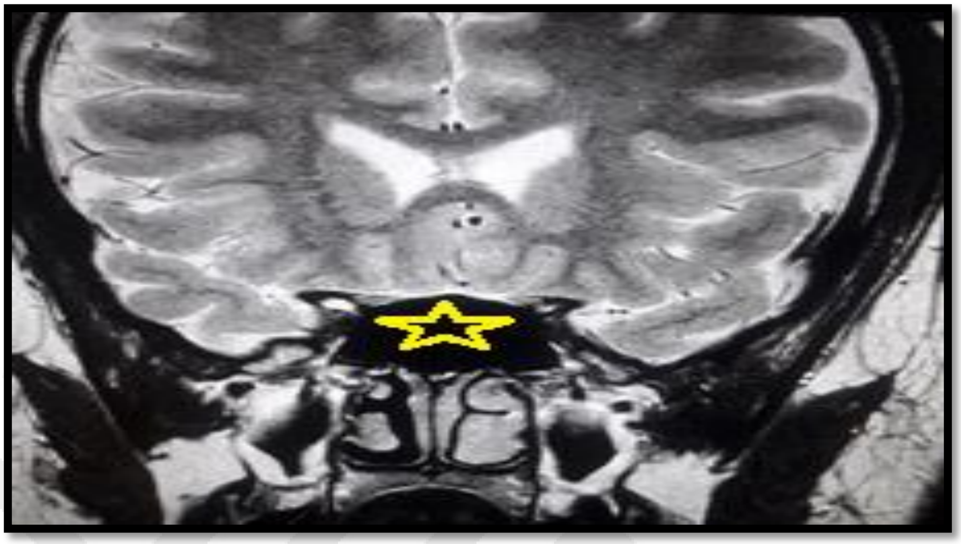
ON: Optic nerve
ICA: Internal carotid artery
Source: This table was prepared by Fatma Alfageih

Figure 4.6: Distribution of the attachment of sphenoid sinus septa



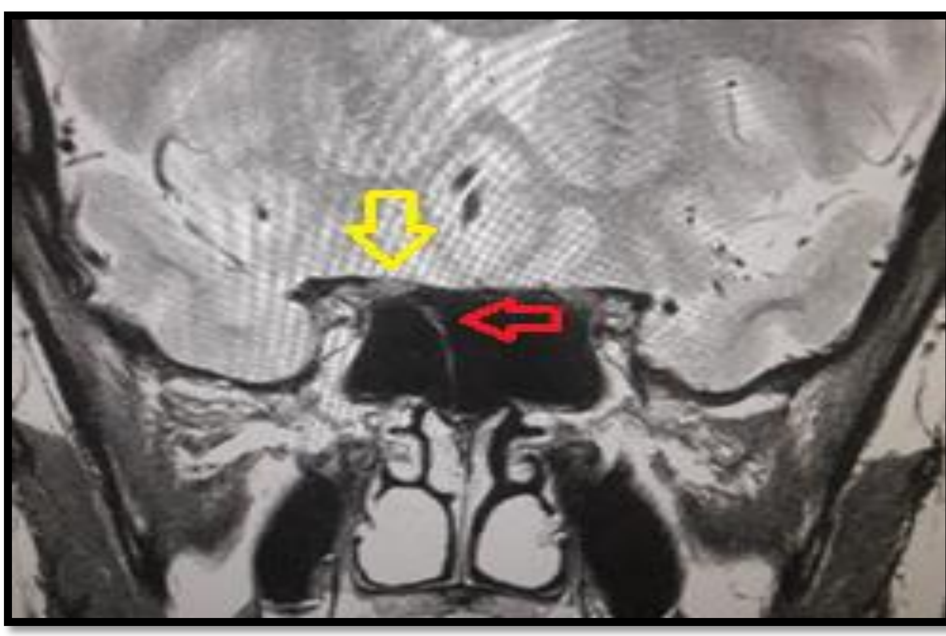
Source: This figure was prepared by Fatma Alfageih

Figure 4.7: Showing coronal MRI scan of aseptate sphenoid sinus



The star indicates to sphenoid sinus
Source: This figure adopted from BAU hospital records and prepared by Fatma Alfageih

Figure 4.8: Shows sphenoid sinus with single septa attached to optic nerve



Septa: Red arrow
Optic nerve: Yellow arrow
Source: This figure adopted from BAU Hospital records and prepared by Fatma Alfageih

Figure 4.9: Showing sphenoid sinus with single septa attached to sella

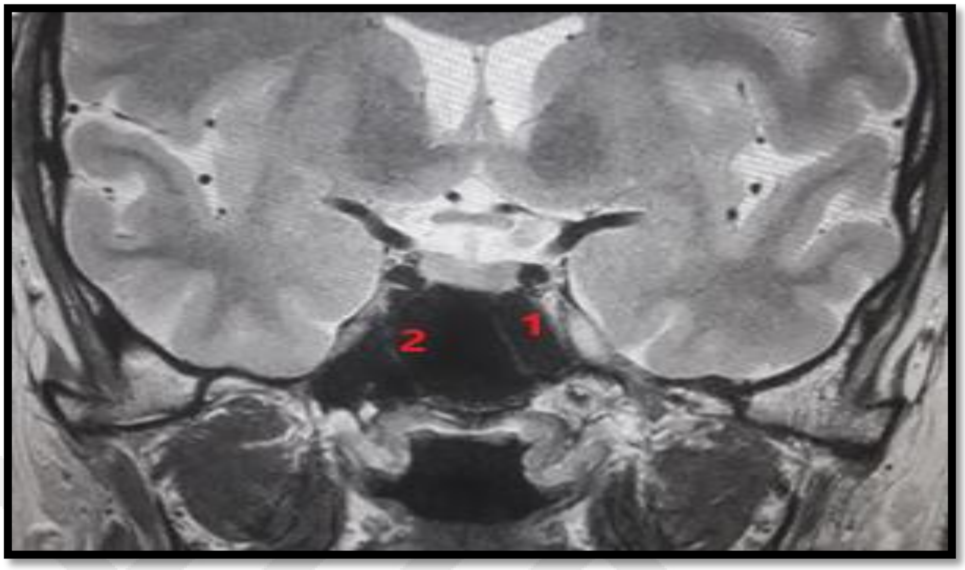
Sella: Red arrow
Source: This figure adopted from BAU Hospital records and prepared by Fatma Alfageih

Figure 4.10: Showing sphenoid sinus with two septa attached to ICA

Septa: Red arrow
ICA: Internal carotid artery (yellow arrow)
Source: This figure adopted from BAU Hospital records and prepared by Fatma Alfageih

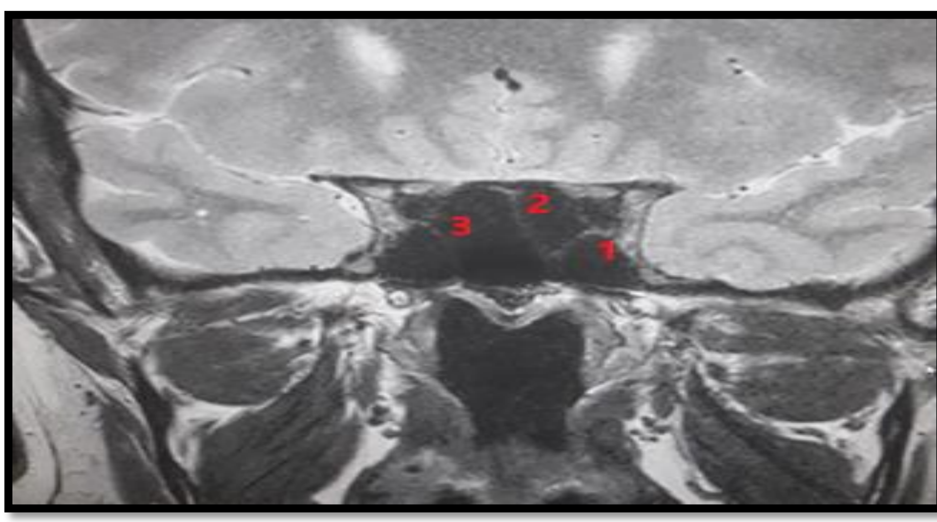
Figure 4.11: Showing sphenoid sinus with double septa attached to sella

and lateral wall of sphenoid sinus



1: Septa attached to sella
2: Seta attached to lateral wall
Source: This figure adopted from BAU Hospital records and prepared by Fatma Alfageih

Figure 4.1: Showing three septa attached to ICA and to sella



1,3: Septa attached to internal carotid artery
2: Septa attached tow sella
Windowing techniques is used to better visualization of septa
Source: This figure adopted from BAU Hospital records and prepared by Fatma Alfageih

4.3 TYPES OF PNEUMATIZATION OF THE SPHENOID SINUS AMONG THE STUDY POPULATION

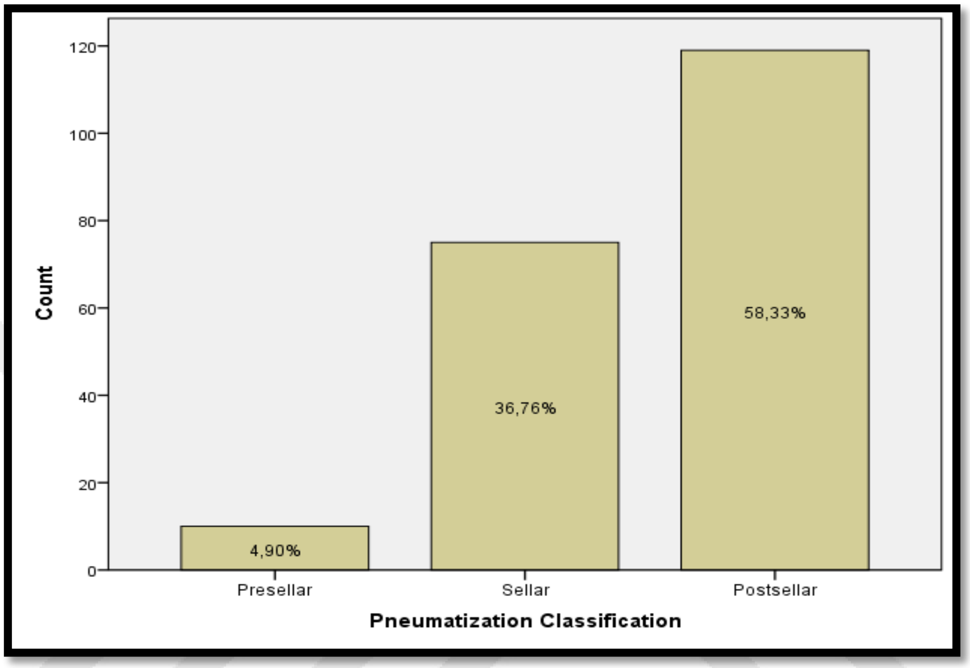
The most predominant type of pneumatization was the postsellar type. There were 119 subjects out of the total study population 204 posses this type of pneumatization (58.3percent) (Figure 4.16). The second common variant of the pneumatization was the sellar type (36.8percent) (Figure 4.15). The least frequent type of pneumatization was the presellar type (4.9percent) (Figure 4.14). The conchal type and a pneumatized variant had not seen among our population. Table 4.8, and Figure 4.13 below presented the distribution of different pneumatization types among the study population.

Table 4.8: the frequency of pneumatization types

Type of Pneumatization	Frequency	Percent
Presellar	10	4.9
Sellar	75	36.8
Postsellar	119	58.3
Total	204	100.0

Source: This table was prepared by Fatma Alfageih

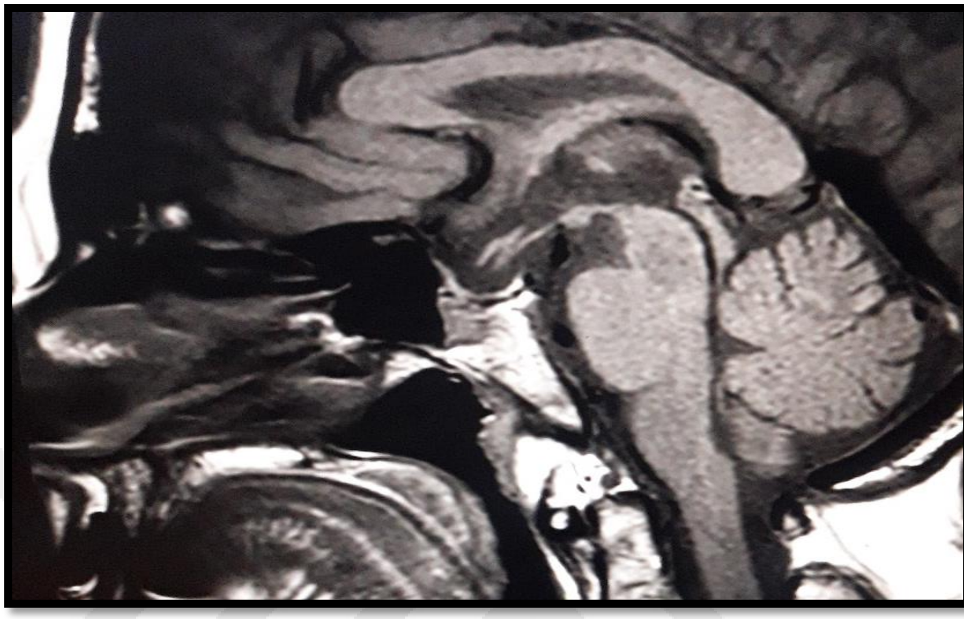
Figure 4.13: Distribution of different pneumatization types



Source: This figure was prepared by Fatma Alfageih

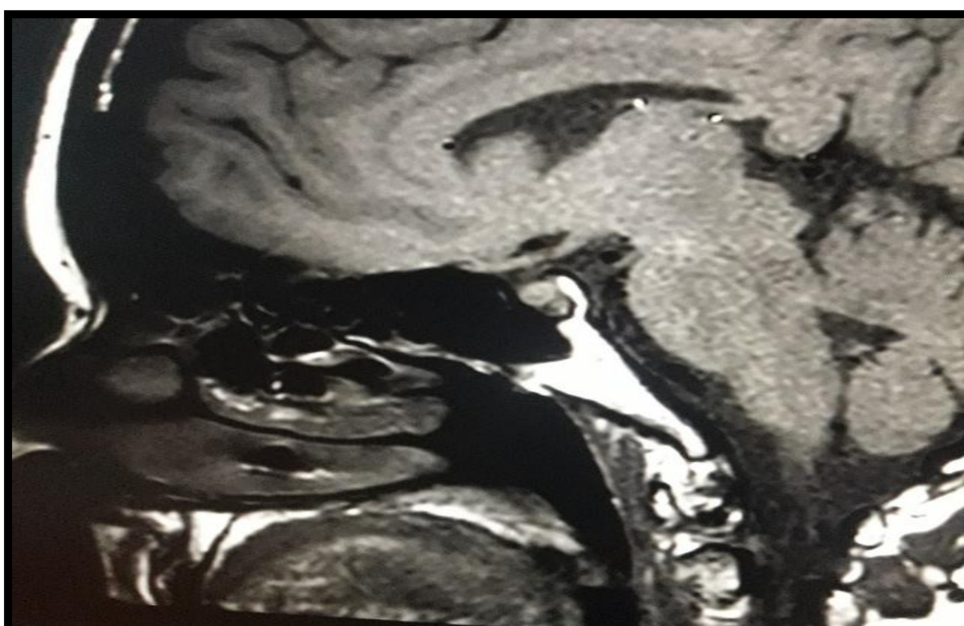
The postsellar type was the most prevalent type among male (45.2percent), and female (61.8percent) gender, while sellar type was 45.2percent in male, and 32.1percent in female, the least frequent type of pneumatization was the presellar in both male (2.7percent) and female (6.1percent). However, the gender variation was statistically insignificant, p value=0.132. Furthermore, there was statistically significant difference between sphenoid sinus volume according to pneumatization types (p value=.000). This difference explained in detail in Table4.10 below. Table 4.9 and Figures 4.17,4.18, and4.19 appear distribution of Pneumatization Types Among male and female.

Figure 4.14: Shows sagittal MRI scan of presellar pneumatization



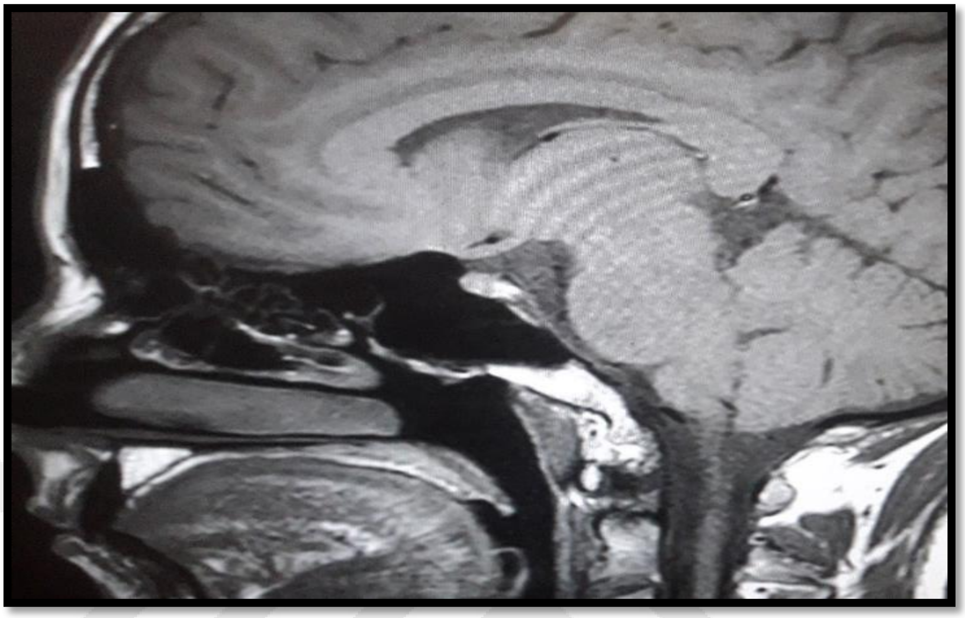
Source: This figure adopted from BAU Hospital records and prepared by Fatma Alfageih

Figure 4.15: Shows sagittal MRI of sellar pneumatization



Source: This figure adopted from BAU Hospital records and prepared by Fatma Alfageih

Figure 4.16: Shows sagittal MRI scan of postsellar pneumatization



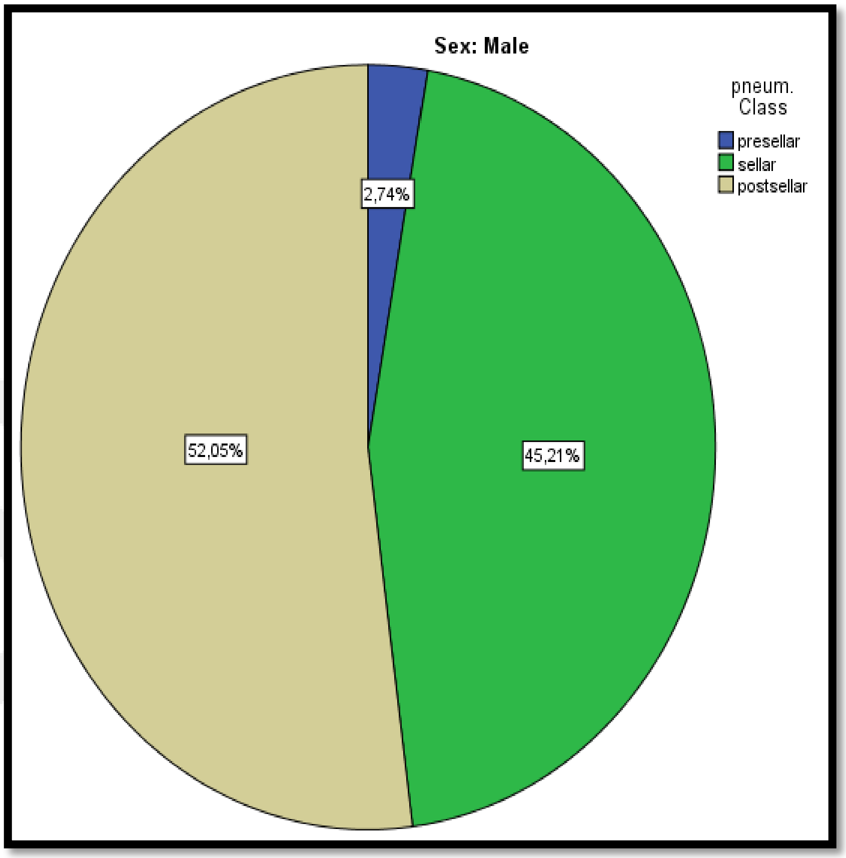
Source: This figure adopted from BAU Hospital records and prepared by Fatma Alfageih

Table 4.9: Distribution of pneumatization types in relation to the gender

Sex	Presellar	Sellar	Postsellar	Total
Male	2(2.7%)	33(45.2%)	38(52.1%)	73(100.0%)
Female	8(6.1%)	42(32.1%)	81(61.8%)	131(100.0%)

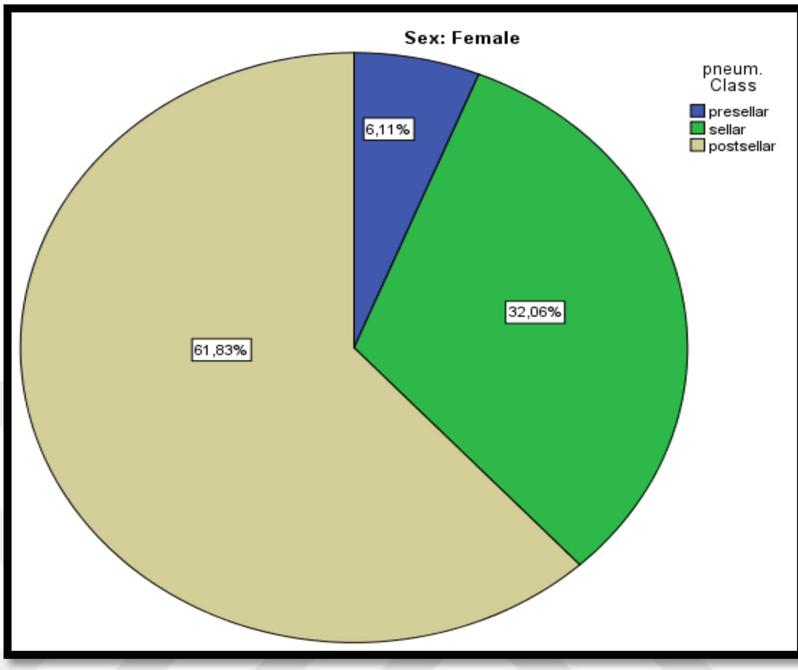
Source: This table was prepared by Fatma Alfageih

Figure 4.17: Distribution of pneumatization types among male



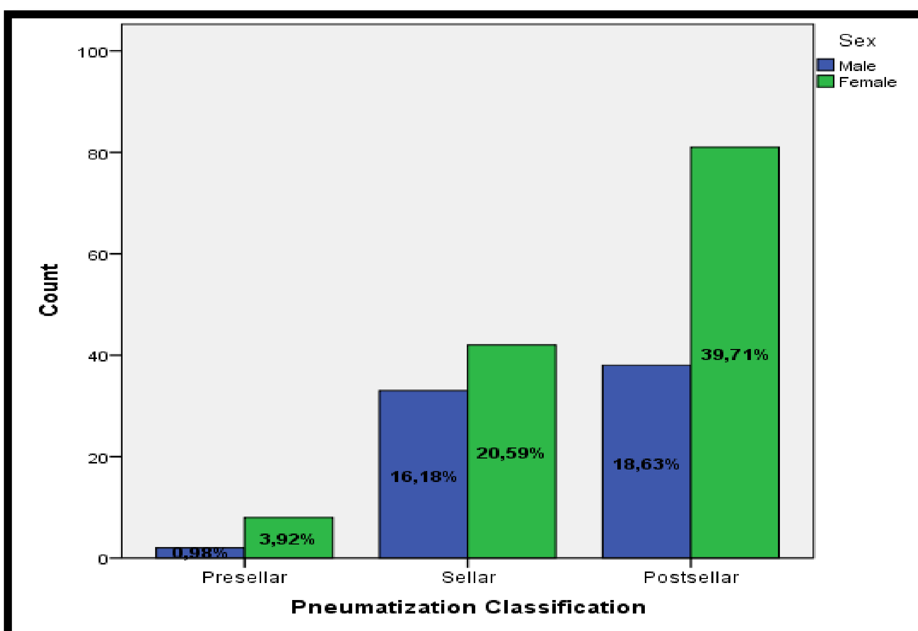
Source: This figure was prepared by Fatma Alfageih

Figure 4.18: Distribution of pneumatization types among female



Source: This figure was prepared by Fatma Alfageih

Figure 4.19: Distribution of pneumatization types among male and female



Source: This figure was prepared by Fatma Alfageih

Table 4.10: Demonstrate the difference in sinus volume between pneumatization types

Pneumatization types	The mean sinus volume (cc)	The median sinus volume (cc)	STD
Presellar	12.8	12.7	4.1
Sellar	21.9	20.2	6.8
Postsellar	25.2	23.8	8.1

cc: Cubic centimeter
STD: Standard deviation
Source: This table prepared by Fatma Alfageih

4.4 OPTIC NERNE AND INTERNAL CAROTID ARTERY PROTRUSIONS AMONG STUDY POPULATION

In this study, there was 43.6percent bilateral protruded optic nerve (Figure 4.22). While 40.7percent of the study population had both sides non-protruded optic nerve into the sphenoid sinus (Figure 4.21). Wherase,15.7percent of the study population were with unilateral ON protrusion (Figure 4.23)60percent in left side and 40percent unilateral ON protrusion in right side. Optic nerve protrusion was more with increased sinus volume P value=0.05, as seen in Table 4.11 below. While the difference between male and female was statistically nonsignificant p=0.07. The frequency of optic nerve variation is summarized in Table 4.12 and Figure 4.20 below.

Table 4.11: Demonstrates the relation between sinus volume and ON protrusion

	The mean sinus volume(cc)	The median sinus volume(cc)	STD
No ON Protrusion	21,83	20,76	7,91
Unilateral ON Protrusion	23,02	21,18	8,49
Bilateral ON Protrusion	25,03	23,93	7,84

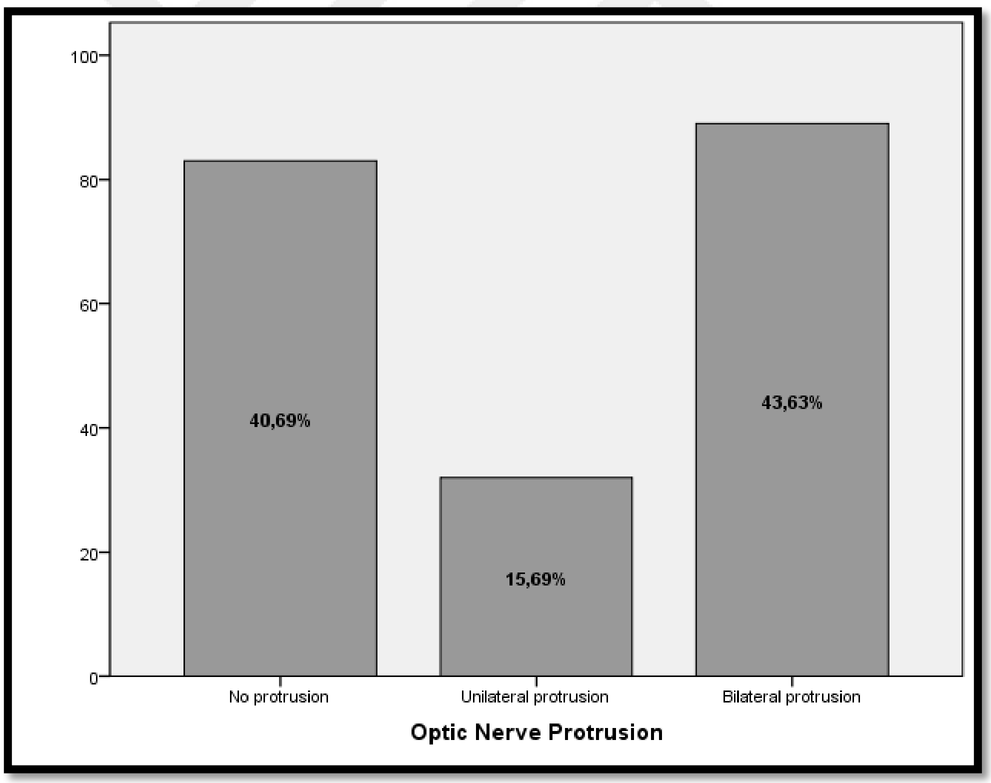
cc: cubic centimeter
STD: Standard deviation
Source: This table was prepared by Fatma Alfageih

Table 4.12: Optic nerve relation to the sphenoid sinus

Variation	Frequency	Percent
Bilateral non-protruded ON	83	40.7
Unilateral protruded ON	32	15.7
Bilateral protruded ON	98	43.6
Total	204	100.0

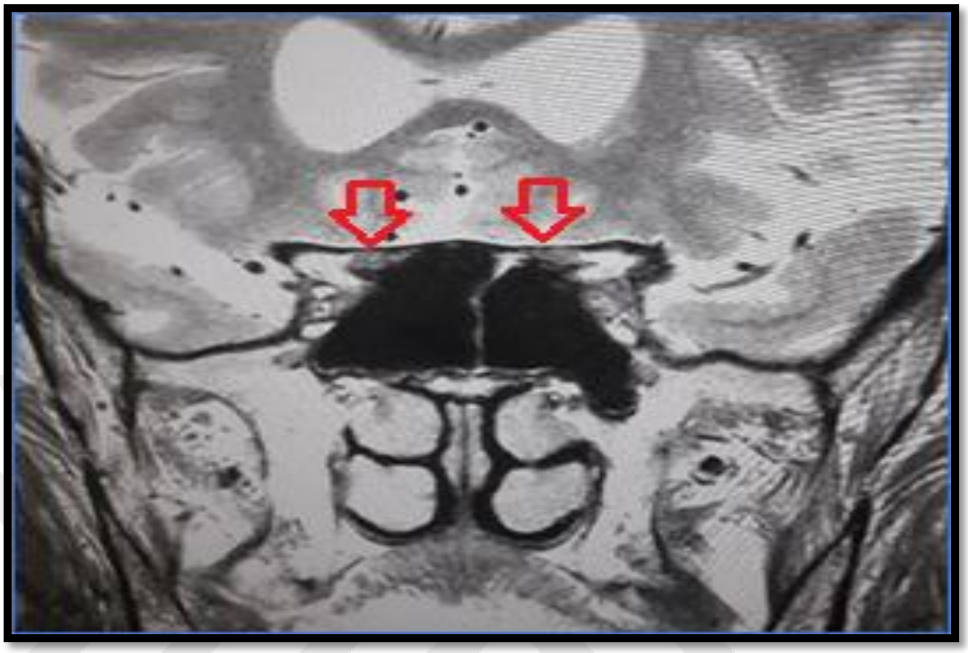
Source: This table was prepared by Fatma Alfageih

Figure 4.20: Distribution of optic nerve relation to the sphenoid sinus



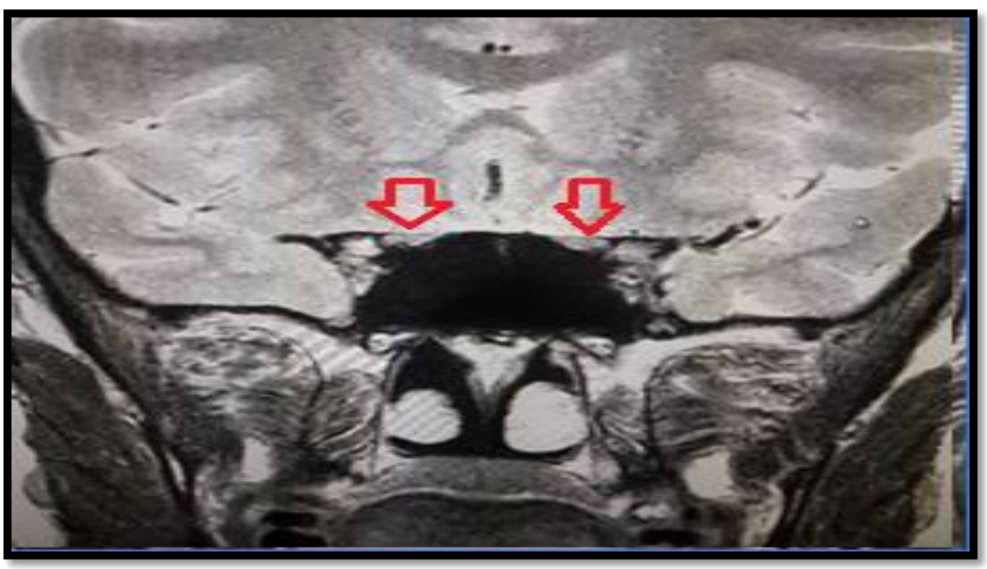
Source: This figure was prepared by Fatma Alfageih

Figure 4.21: Showing bilateral non-protruded ON



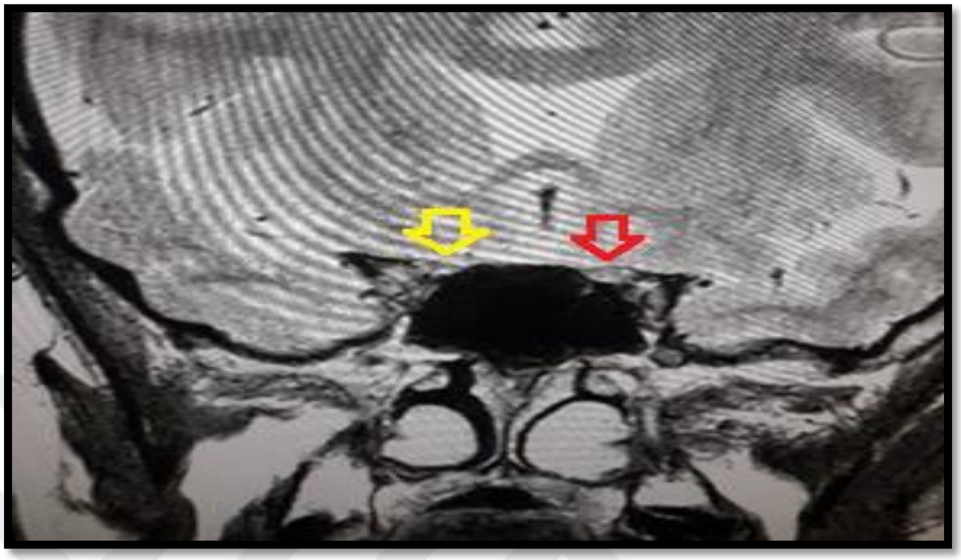
ON: Optic nerve (red arrows)
Source: This figure adopted from BAU Hospital records and prepared by Fatma Alfageih

Figure 4.22: Showing shows bilateral protruded ON



ON: Optic nerve (red arrows)
Source: This figure adopted from BAU Hospital records and prepared by Fatma Alfageih

Figure 4.23: Showing right non-protruded left protruded ON



ON: Optic nerve
Yellow arrow:Non-protruded ON
Red arrow : Protruded ON
Source: This figure adopted from BAU Hospital records and prepared by Fatma Alfageih

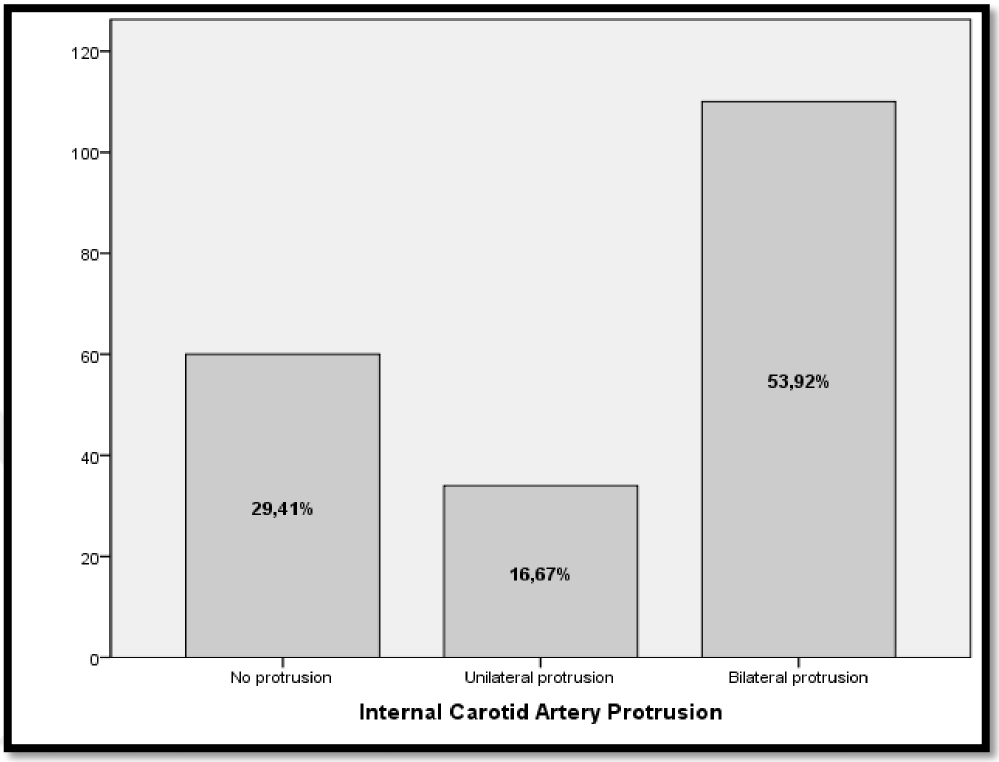
Moreover, bilateral protruded ICA found in 53.9percent of the study population was seen in Figure4.26. Also, both sides of the ICAs were not seen protruding into the sphenoid sinus in 29.4percent of the study population (Figure 4.25., While, 16.6percent of the study population were with unilateral protruded ICA,50percent in each side (Figure 4.27). There was no correlation between sinus volume and ICA protrusion p value=0.1. Also, gender difference was statistically insignificant, p value=0.095. In detail, the frequency of internal carotid artery variation is summarized in Table 4.13, Figure 4.24 below.

Table 4.13: Internal carotid artery protrusion in to the sphenoid sinus

Variation	Frequency	Percent
Bilateral non-protruded ICA	60	29.4
Unilateral protruded ICA	34	16.4
Bilateral protruded ICA	110	53.9
Total	204	100.0

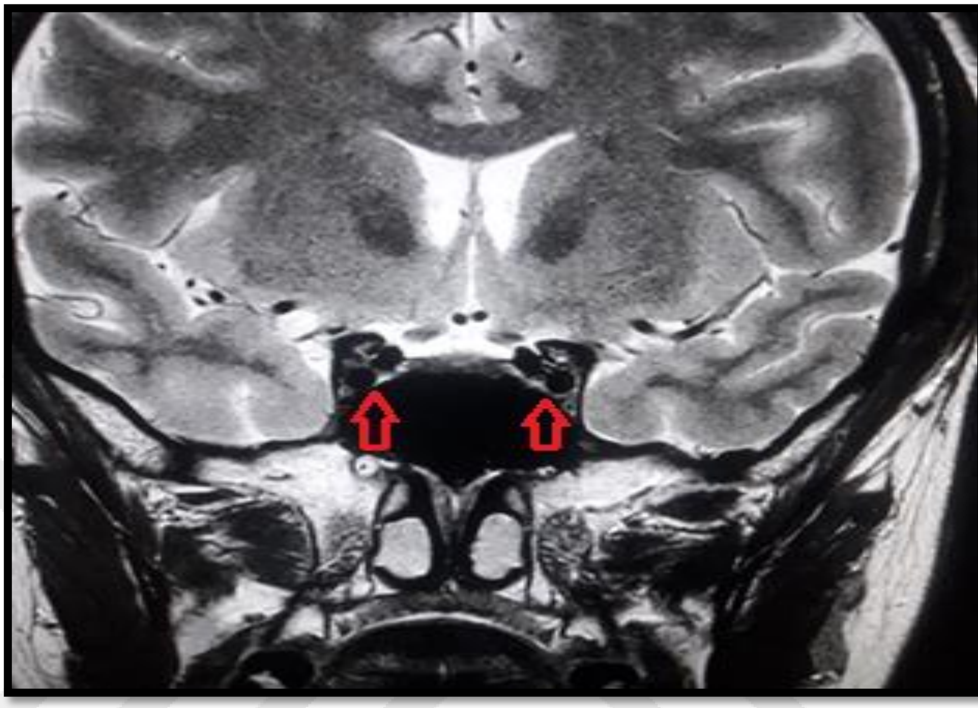
Source: This table was prepared by Fatma Alfageih

Figure 4.24: Distribution of internal carotid artery in relation to sphenoid sinus



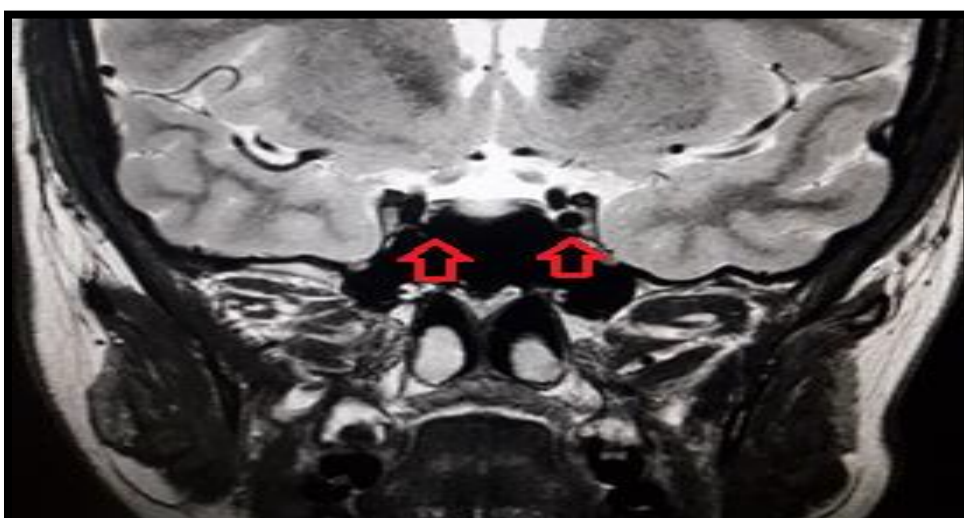
Source: This figure was prepared by Fatma Alfageih

Figure 4.25: Shows bilateral non-protruded ICA



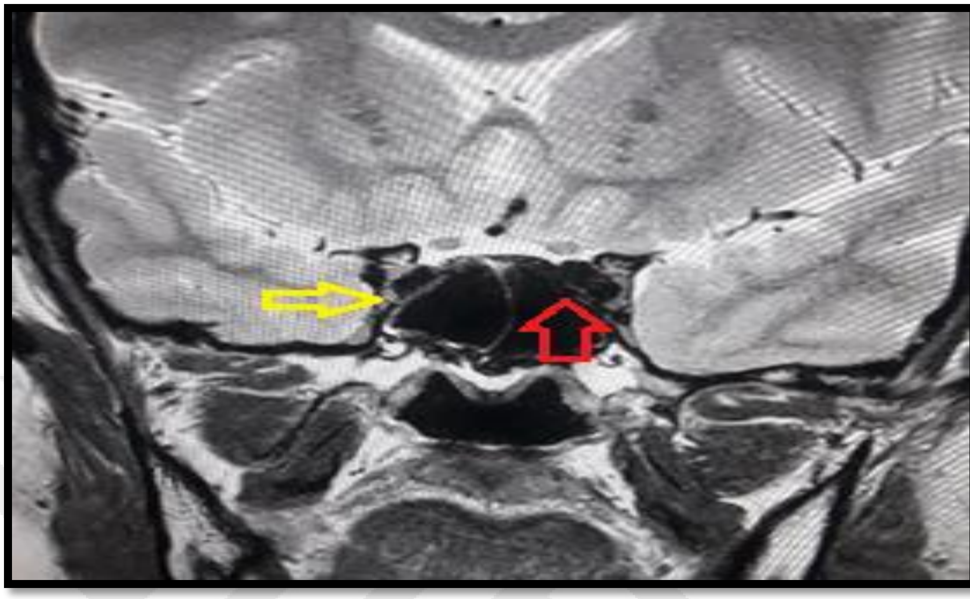
ICA: Internal carotid artery (red arrows)
Source: This figure adopted from BAU Hospital records and prepared by Fatma Alfageih

Figure 4.26: Shows bilateral protruded ICA



ICA: Internal carotid artery (red arrows)
Source: This figure adopted from BAU Hospital records and prepared by Fatma Alfageih

Figure 4.27: Shows right non-protruded left protruded ICA



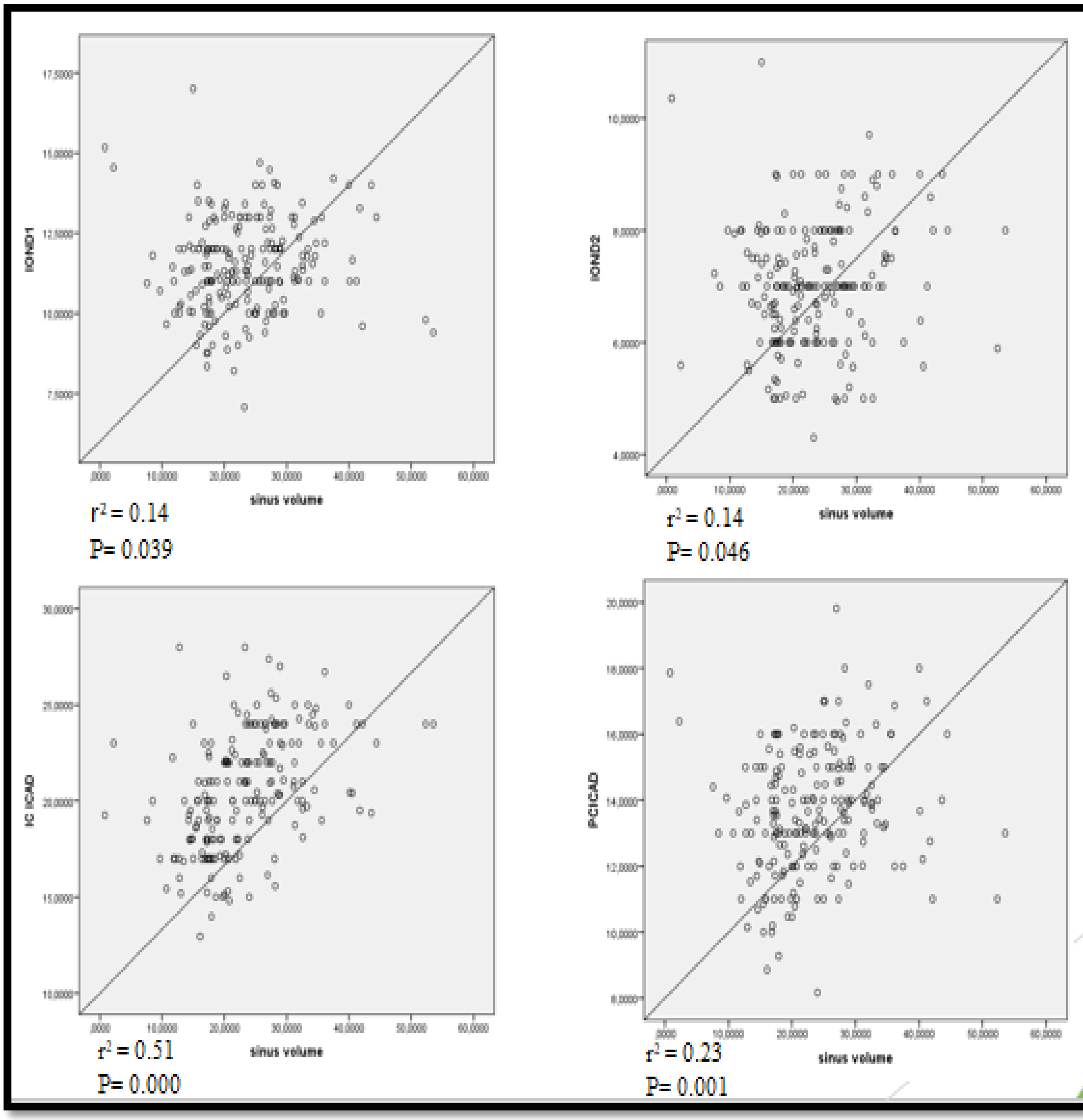
ICA: Internal carotid artery
Yellow arrow: Non- Protruded ICA
Red: Protruded ICA
Source: This figure adopted from BAU Hospital records and prepared by Fatma Alfageih

4.5 INTER OPTIC NERVES AND INTER CAROTID ARTERIES DISTANCE

The mean intracranial inter optic nerve distance (IOND)1 in our study was 11.48±1.4mm, IOND2 was 7.0±1.2mm.the differences showed no statistically significance between gender and IOND. Whereas, the relation between IOND and sinus volume was statistically significant. IOND1p=0.039, IOND2 p=0.04.

On the same extend, inter carotid distance (ICD)was measured between two cavernous carotid arteries (CICD), and tow paraclinoid segments (PICD), the mean CICD was 20.53±3mm, while, the mean PCICD was 13.72±2 mm. the same as for IOND, sex difference was statistically nonsignificant. Also, there was a correlation between the CICD and sinus volume p value=,000, PICD as well was significantly more in larger sinus volume p=, 001.Figure 4.28 shows the correlation between sinus volume and the distances separate the optic verves, and the cavernous and paraclinoid segments of internal carotid arteries.

Figure 4.28: Shows the relationship between sinus volume and inter optic and inter carotid distance



r^2: The coefficient correlation
P: Probability
Source: This figure was prepared by Fatma Alfageih

5. DISCUSSION

The sphenoid sinus has attracted attention over the past decade because of it is important location which is deeply in the center of the skull, that makes it an important entrance to various diagnostic techniques, selective endoscopic approaches to the sellar region and advancement of surgery.

The extension of the sphenoid sinus is important not only for providing alternative surgical approach, in addition, itis related to important vital structures as nerves and vessels which can be evaluated and investigated. Sphenoid sinus was considered as the most inapproachable sinus. At the present time, with innovation in the functional endoscopic surgery and advanced imaging technique, the sinus can be accessed with less difficulties. The advantage of the transsphenoidal approach over the transcranial is grounded on the fact that the former is the least traumatic route to the skull base; it avoids brain retraction and provides excellent visualization of the region.

As the sinus make available to access to adjacent structures such as the base of the skull, and pituitary gland. This increased the significance of looking at carefully to the detailed anatomy and variation of the sphenoid sinus. Subsequently, precise acknowledgement of the sphenoid anatomy would decrease the devastating injury to the related neurovascular structures, namely the internal carotid artery and the optic nerve.

Attributable to a wide anatomical variation of the sphenoid sinuses among the population, many of searches has been performed using different investigation methods. The sphenoid sinus varies in its size, pneumatization, relation to the optic nerve, and internal carotid artery. The modern radiological imaging of the sphenoid sinus provides a clear and detail images of these variations. In turn to decrease the complications of the endoscopic sinus surgery, preoperative imaging is highly recommended.

5.1 SPHENOID SINUS VARIATION

5.1.1 Sphenoid Sinus Volume

Defining the sphenoid sinus size very important prior to transsphenoidal procedures, it can predict the risk of accidental surgical damage to the surrounding neurovascular structures(Li et al. 2014, p.2).

Sphenoid sinus volume had been measured using different methods. Studies done by Cohen et al. (2017, pp. 96–102), Li et al. (2014, p.2), Oliveira et al. (2009, pp. 390–393), and Yonetsu et al. (2000, pp. 453–472) different Softwires were used to calculate sphenoid sinus in three-dimension images. Whereas Selcuk et al. (2015) and Li et al. (2014, p.2) calculated the volume by measuring the three dimensions of the sphenoid sinus in plane images.

In present study the mean volume of the sphenoid sinus calculated by measuring its dimensions (height, length, width) on MRI. The mean sinus volume was 23,42 ± 8,07 (cc), which is less than reported by Cohen et al. (2017, pp. 96–102) and Oliveira et al. (2009, pp. 390–393). The volume of the sphenoid sinus ranges from eight cubic centimeter to a maximum volume of 54 cubic centimeters. Also, it is important to mention that, in our study the measured volume is for both sinus compartments in other study. While, Oliveira et al. (2017, pp. 367–374) reported volume of sphenoid sinus was 6cc on right side, and 7cc in left side.

Oliveira et al. (2009, pp. 390–393) found the minimum volume of the sphenoid sinus is 3.3cc and the maximum is 24.25 cc. In this study there was significant statistical variation between male and female mean volumes. The mean volume of the male is 27.32cc while the mean volume of the female is 21.24 cc. This means the volume of the male is higher than that of female subjects. This result corresponding to research by Oliveira et al. (2009, pp. 390–393) and Gibelli e al. (2018, pp. 193–198). In former study male mean volume was 15.4 cc and female mean volume was 10.8cc. Whereas, the second study reported sphenoid sinuses volume in males was 10cc, in females 8cc. While the researcher Oliveira (2017, pp. 367–374) and his group determined no significant correlation between gender and volume.

The Table 5.1 below demonstrates previous literature on the sphenoid volume. As has been noted sphenoid sinus volume has a wide range. Theses variation in the volume due to use of different manual methods of measurement and there is no fully automated method. Moreover, the volume of the sinus is age dependent so the volume in the previous literature varies according to age group included in the research.

Another contribution to this variation is the type of sphenoid sinus pneumatization. Some other studies also demonstrate ethnic sphenoid sinus volume variations. Actually, the sphenoid sinus volume could predict the pneumatization pattern of the sinus as stated by Ramalho et al. (2017, pp. 162–167), the post sellar type had a higher volume than others. On the same extends Gibelli et al. (2018, pp. 193–198) found that sphenoid sinus volume convincingly differs upon the type of sinus pneumatization.

Furthermore, the studier Yonetsu et al.(2000, pp. 453–472) stated that there was no difference in volume aeration between men and women, which is in agreement with our results.

Consequently, the surgeon could expect the safety of sinus related neurovascular structures during the endoscopic sinus surgery. Variation of sinus volume in this study compared with other studies illustrated below (Table5.1).

Table 5.1: Variation in volume means in our study compared to other studies

Author	Place	Sample size	Mean age/year	Mean volumes/ cubic centimeter
Oliveira et al. (2009)	USA	150 CT	-	13.14
Li et al. (2014)	China	350 CT	25-64Y	14.2
Selcuk et al. (2015)	Turkey	115 CT	18-67Y	7.8
Ramalho et al. (2016)	Brazil	47 CT	18-86Y	6.6
In present study	Turkey	204 MRI	14-70Y	23.4

CT: Computed tomography
MRI: Magnetic Resonance Imaging
Source: This table prepared by Fatma Alfageih

5.1.2 Sinus Septation Number And Its Attachment Site

Sphenoid septum located inside the sinus cavity divides it into compartments. Sphenoid sinus differs in the number of the septa, as well as in the site of septa attachment.

Little studies were done on the sphenoid sinus septation and attachment, in the most of previous studies they have used CT scan images. In this study found aseptate sphenoid sinus in 9 patients of the study population (4.4percent). This was seen in 7 female subjects and 0 male subjects.

The investigator Abdullah et al. (2001, pp. 185–188) evaluated the sphenoid sinus septation, and it is relation to ICA among seventy patients; 28Chinese,24Indian, and 18Malaysian population, 50percent male, and 50 percent female, using five-millimeter thickness CT scan slices. They reported that the majority of cases had multiple septate sphenoid sinuses (85.7 percent).

A Study had done by Kapur et al.(2012)reported 2percent had aseptate. While, Kashyap et al. (2017, pp. 955–959) reported 5 percent with equal gender distribution, which was no much difference to our result finding. This research demonstrates a single septum in 61.8 percent of the study population and it is seen higher in females (45 percent) than males (36.5 percent). While Kashyap et al. (2017, pp. 955–959) reported a higher prevalence (67 percent) of single septa. No gender distribution was reported.

Conversely, the frequency of the two septa in our study was 21.1 percent, which was corresponded to (Kashyap et al. 2017, pp. 955–959) findings (21.25 percent). This study demonstrates almost equal frequency of three septa between male (44 percent) and female (41.5 percent) gender. No available literature was found to compare with. In addition, three septate sphenoid sinuses were seen in our study in 10.8 percent of the study population which higher than observed by Kashyap et al. (2017, pp. 955–959) (6.25 percent). Three septa were prominently seen among male (25.7 percent) than female gender (10 percent) among the studied population.

Eventually, two percent of our study population observed with four sphenoid sinus septa. This was lower than what was reported by Kapur et al. (2012), who manifested five males' gender out of 200 subjects with four septate sphenoid sinuses. The relation of the septa to the neurovascular structures surrounding the sphenoid sinus make these structures at higher risk of injury during endoscopic sinus surgery. Therefore, a preoperative determination is significantly important for a safe procedure. We have proved that MRI is a good method to demonstrate the sinus septation.

A varied range of variant of sphenoid septa attachment. The table 5.6 below demonstrates a previous prevalence of different attachment sites compared with our finding. Aseptate sinus was seen in 4.4 percent of our study population which is was almost equal to the prevalence reported by Kashyap et al. (2017, pp. 955–959), which was (5 percent). While the frequency of sphenoid septa connected to the sella was the highest in our study population (40.2 percent). This was higher than the Kashyap et al. (2017, pp. 955–959) finding (26.25 percent). Sella and internal carotid attachment were the second common variant of septum attachment (15.7 percent) compared with no much difference in the prevalence (11.25 percent) had shown by Kashyap et al. (2017, pp. 955–959).

The third popular attachment site of sinus septa in the present population was internal carotid artery (14.7percent). While Kashyap et al. (2017) reported a distinguishable higher frequency (35 percent) than represented by our study. Moreover, Abdullah et al. (2001) (31.1 percent), Fasunla et al. (2012, pp. 57–64) (4.5 percent), the reported prevalence of ICA septum attachment ranges from 4.5 percent to 35 percent. Similarly, this work reported frequency ICA attachment was within the range of the previous literature.

Septa connected to the optic nerve was seen in 12.3 percent of our study population. Whereas it is reported by Kashyap et al. (2017, pp. 955–959) at much lower frequency (2.5 percent). Furthermore, nearly equal frequency of our study population was attached to the lateral wall, and to the ON and ICA (3.9 percent) and (3.4 percent), which is less than stated by Kashyap et al. (2017, pp. 955–959). Septa attached to the lateral wall was 12.5 percent. Likewise, ON and ICA attachment was not reported.

Septa related to the internal carotid artery and the lateral wall was seen only in 2 percent of our study population. Whereas it is reported by Kashyap et al. (2017, pp. 955–959) at a higher frequency (6.25 percent).

The frequency of sphenoid septa connected to the sella, lateral wall, and ICA was 2.0 percent, a little higher than that reported by Kashyap et al. (2017, pp. 955–959) (1.25 percent). In Table 5.2 below shows the number and frequency of attachment sites of the sphenoid septa in previous researches compared to present study.

Table 5.2: The attachment sites of the sphenoid septa in previous researches compared to our findings

Author	Place of study	Sample size	Imaging technique	No septa attachment %	Sella %	ICA %	ON %	Lateral wall %	ICA+ Sella %
Abdullah et al. (2001)	Malaysia	70	CT	-	-	31	-	-	-
Fasunla et al. (2012)	Nigeria	110	CT	-	-	4.5	-	-	-
Kashyap et al. (2017)	India	80	CT	5	26	35	2.5	12.5	11.25
In present study	Turkey	204	MRI	4.4	40.2	14.7	12.3	3.9	15.7

CT: Computed tomography
MRI: Magnetic Resonance Imaging
ON: Optic nerve
ICA: Internal carotid artery
Source: This table was prepared by Fatma Alfageih

Ultimately, another variation in septum attachment was seen in our study population, septum related to sella and lateral wall (1.5percent). There was no available data to compare these results. Its fundamental to the neurosurgeon and otorhinolaryngologic to evaluate the inter-sphenoid sinus septa attachment sites preoperatively, as sphenoid septum sometimes connected to the internal carotid artery and optic nerve rendering their injury during surgical dissection of the septa, hence assessment of attachment site protects these structures from being damaged (Anusha et al. 2015, pp. 1183–1190).

The obtained reports from the previously offered works and from our study finding together asserts that the sphenoidal septum cannot be considered as a dependable landmark for trans sphenoidal procedures. Its position, as we came to know from our study, is not always in the midline, but shifted to either right or to left side at least in parts of its entire length from anterior to posterior end. Also, the frequency of insertion of the sphenoid septa differs significantly between individuals. A carful preoperative radiological evaluation is necessary in order to protect the surrounding neurovascular structures from injury.

5.1.3 Pneumatization

Sphenoid sinus pneumatization ranges from absent of aeration to massive aeration that extends to involve anterior clinoid, pterygoid processes, greater wings of sphenoid, and clivus.

Information obtained from the previously current studies, the pneumatization types of the sinus differ among population. Radberg, Hammer and other (1961) classify pneumatization into 3 forms namely conchal, presellar, and sellar. Another author called Lang's add forth post sellar type (Hammer and Radberg 1961, pp. 401–422).

Furthermore, Hammer and Radberg classification adapted by Dias, Albernaz and Yamashida(2004, pp. 651–657).They classify pneumatization into five types by adding a pneumatized type to the above four type. This research adopted and studied for all five types of pneumatization.

Many literatures provide a demonstration that the sphenoid sinus pneumatization changes with age. Our analysis chose the age group of 14-70. This was based on previous reports. The aeration starts to develop at age of 2 years and continuous up to age 14years. Yonetsu et al. (2000, pp. 453–472) found that, sinus pneumatization started at 5 years old. As well, they noticed reduction in the sinus volume by the age of 70 years to 71percent of its maximum volume.

In many of previous investigators found that the sellar type is the most prevalent type of pneumatization (Gibelli et al. (2017, pp. 193–198), Anusha et al. (2015, pp. 419–427) and Kayalioglu et al. (2005, pp. 79–84)). For more explanation, Anusha et al. (2015, pp. 419–

427) illustrated the prevalence of pneumatization types in Malaysian subjects with a majority of sellar type (93percent), followed by the presellar type (6.7percent), followed by conchal type (0.3percent).

Similarly, another study on Malaysian, Hindi et al. (2014, pp. 429–436) demonstrated dominance of postsellar type (83percent) followed by (16.7percent) prevalence of presellar type with no conchal type was seen in his study.

Likewise, study done by Vaezi et al. (2015, pp. 577–581) informed a prevalence of 73percent, 23percent, 2.5percent for sellar, presellar, and conchal types respectively among 102 American population.

However, the above pneumatization types frequencies differ from the frequencies founded in our study. In which post-sellar type is the most predominant type (58.3percent), the second predominant is sellar type (36.8 percent), the third is presellar type (4.9 percent), and the conchal type was absent among our study population.

Battal et al. (2014, pp. 232–237) who studied the prevalence of different pneumatization types among 314 Turkish population and reported that postsellar type was the most prevalent type (68percent). Correspondingly Oliveira et al. (2017, pp. 367–374) demonstrate the types of frequencies 61 percent, 23.7 percent, 12.76 percent, 2.12 percent for post-sellar, sellar, presellar, and conchal respectively.

According to Rahmati et al. (2016, p.32) post-sellar type is the most prevalent (83 percent) pneumatization type among 103 Iranian subjects, followed by sellar 14.6 percent, presellar 1.9 percent and no conchal type was seen. this supports our finding.

Additionally, there are few studies which reported the pneumatization types in relation to gender. In our study, the postsellar type was the most prevalent type among male (45.2percent), and female (61.8percent) gender, while sellar type was 45.2percent in male, and 32.1percent in female, the least frequent type of pneumatization was the presellar in both male (2.7percent) and female (6.1percent). Nevertheless, the gender variation was statistically insignificant.

In contrast to our finding, Rahmati et al. (2016, p.32) depicted that males were more than females having post-sellar type. While Kayalioglu et al. (2005, pp.97-84) reported that post-sellar type mainly had seen among female gender (22.2 percent), and conchal type was only found in female gender (1.7 percent).

Knowledge gained from the above available literatures and from the findings of our present study together stated that the pneumatization changes with age. Also, this difference in the frequency could referred to variances in classification types, that means it cannot be taken as a significant landmark for endoscopic surgery, as it has been noted above the frequency of pneumatization types of the sphenoid sinus differ from literature to another that could be a consequence of variation in the sample size.

The difference in age group included in the study as stated by many literatures that the pneumatization changes with age. Also, this difference in the frequency could referred to variances in classification types.

In this study, the post-sellar type is the most prominent type as the age of included subjects limited to 70 years old. While in some previous researches include subjects with age more than 70 years demonstrated the predominance of sellar type. This additionally supports what had been stated by Yonetsu et al. (2000, pp. 453–472) who found the pneumatization decrease after the age of sixty years.

Simultaneously, the various classification of sphenoid sinus pneumatization that had followed by researchers similarly increase the diversity in the frequency between literatures.

Frequencies of pneumatization types in preceding literature compared to our results demonstrated below in Table5.3.

Table 5.3: Frequencies of pneumatization types in previous literature compared to this study

Study	Year	place	Sample size	Age Y	Imagine technique	Conchal Type%	Presellar Type%	Sellar Type%	Postsellar Type%
Kayalioglu et al	2005	Turkey	180	20-75	MRI	1.9	9	52.9	36.2
Baldea and Sandu	2012	Romania	50	10-86	CT	14	44	82	2
Battal et al	2014	Turkey	314	18-89	CTA	1	18.2	12.7	68
Hindi et al	2014	Malaysia	150	18-89	CT	0	16.7	-	83
Viday	2015	India	80	40-60	skulls	-	10	85	5
Anusha et al	2015	Malaysia	300	18 and above	CT	0.3	6.5	93	-
Vaezi et al	2015	USA	102	18 and above	CT	2.5	23	73	-
Rahmati et al	2016	Iran	103	20 and above	CT	0	1.9	14.6	83.5
Oliveira et al	2017	Brazil	47	18-86	CT	2.12	12.76	23	61.7
Gibelli et al	2017	Italy	300	25-99	CT	-	8	77.3	14.7
Present study	2019	Turkey	204	14-70	MRI	0	4.9	36.8	58.3

CTA: Computed Tomographic Angiograph
CT: Computed tomography
MRI: Magnetic Resonance Imaging
Source: This table was prepared by Fatma Alfageih

5.1.4 Optic Nerve Protrusion

In this study, the bilateral protrusion of the optic nerve was found in 43.6percent. While 40.7percent of the study population had both sides non-protruded optic nerve into the sphenoid sinus, it was not referred in the available literature to compare with. Wherase,15.7 percent of the study population were with unilateral ON protrusion 60percent in left side and 40percent unilateral ON protrusion in right side

In spite of different prevalence values. Conspicuously, there is a wide range in the prevalence values of optic nerve protrusion in the available literatures its ranges from 8percent up to65 percent. In fact, it was supported by the present study finding which is (43.6 percent) for optic nerve protrusion. In the case of protrusion, optic nerve damage can occur due either to surgical trauma or as a complication of sinus disease. The risk of blindness is high if the surgeon damages the nerve within the sinus(Maniglia, 1989, pp. 276–283). Moreover, visual deficits may result from a sphenoid sinus infection or from a mucocele compressing the optic canal or nerve. Compression of the optic nerve can cause ischemia and venous congestion of the nerve. Furthermore, the optic canal is the place where optic nerve is least nourished, which makes it very susceptible to injury(Sofferman, 1995, pp. 1–38). To explain the optic nerve relation to the sphenoid sinus in detail as presented below in table 5.4 compared to other literature.

The result of this study was disagreed with what had been found by Dessi et al. (1994) in studying optic nerve protrusion into paranasal sinuses. He recognized fewer prevalence (8percent) of optic protrusion seen bilaterally while our result was (43.6percent) for bilateral optic nerve protrusion.

On the other side, our finding was near to finding of study done by Fasunla et al. (2012, pp. 57–64), ON protrusion was found in 38.2percent of study population. Prevalence of on protrusion among previous literature compared to current study explained in table 5.4 below.

Table 5.4: Prevalence of ON protrusion among previous literature compared to present study

Study	Year	Place	Sample size	Imaging technique	Optic nerve Protrusion%
Dessi et al	1994	Germany	150	CT	8
Heskova et al	2009	Slovakia	34	CT	35.3
Mamatha et al	2010	India	20	CT	65
Fasunla et al	2012	Nigeria	110	CT	38.2
Li et al	2014	China	350	CT	16
Anusha et al	2015	Malaysia	300	CT	2.3
Present study	2019	Turkey	204	MRI	55

CT: Computed tomography
MRI: Magnetic Resonance Imaging
Source: This table was prepared by Fatma Alfageih

Presence of the differences in the frequency of the optic nerve protrusion among population could be referred again to age and gender variation of the study population. Additionally, presence of heterogeneity in considering protrusion of ON. For instance, some authors identify protrusion as an indentation of sphenoid sinus cavities with more than half of ON diameter. In our study, any degree of optic nerve indentation is considered as protrusion as seen on the coronal plane images.

5.1.5 Internal Carotid Artery Protrusion

Internal carotid artery produces bulging on the lateral wall of the sphenoid sinus. It is the most medial structure in the cavernous sinus. This increase the risk of massive bleeding during any procedure around the sphenoid sinus.

We found protrusion of internal carotid artery into the sphenoid in 53.9percent of patients which is higher than Li et al. (2014, p.2), Unal et al. (2006), and Sirikci et al. (2000) Findings;29.4 percent, 30.3percent, 26.1 percent respectively (Li et. Al(.2014, p.2), Unal et al.(2006, pp. 195-201), (Şirikci et .al. 2000, pp. 844–848)). These obviously were high rate of ICA protrusion most likely explained by our criteria for defining protrusion. In our present study, presence of the circumference into the sinus cavity, at any degree, was enough to define protrusion.

Whereas, Sirikci recognized protrusion of internal carotid artery into the sphenoid sinus as the presence of more than half the circumference of the concerned structures into the sinus cavity.

Non-protruded ICA variation was seen in 29.6 percent of study population, it was less than Li et al. (2014, p.2) Finding who found 70 percent had non-protruded ICA.

Furthermore, we found that the most of the protruded ICA were seen bilaterally, unilateral protrusion observed in 16.4 percent. This agreed with Li et al. (2014, p.2) finding who reported the prevalence of the protrusion as (20.57 percent; 8.68 percent) for bilateral and unilateral protrusion respectively. In contrary Mamatha et al. (2010, pp. 121–124) found the lowest prevalence of protruded ICA was seen bilaterally 15 percent and unilateral prevalence was 35 percent.

To summarize, there is a wide range of prevalence of ICA protrusion, our research observed the prevalence of ICA protrusion (53.9 percent) within the mentioned range as it is seen on the Table 5.5 below.

Table 5.5: Internal carotid artery protrusion in other literature compared to present study

Study	Year	Place	Sample size	Imaging technique	ICA Protrusion%
Sethi et al	1995	Singapore	30 cadavers	-	93
Sirikci et al	2000	Turkey	92	CT	26.1
Mamatha et al	2010	India	20	CT	50
Fasunla et al	2012	Nigeria	110	CT	27.3
Li et al	2014	China	350	CT	29
Anusha et al	2015	Malaysia	300	CT	10
Present study	2019	Turkey	204	MRI	62

CT: Computed tomography
MRI: Magnetic Resonance Imaging
ICA: Internal carotid artery
Source: This table was prepared by Fatma Alfageih

This variation among literature in prevalence could be referred to as age group variation and use a method to evaluate these variations. Overall determining ICA relation to the sphenoid sinus preoperatively will definitely help in preventing devastating bleeding within a small closed space that difficult to control.

5.2 THE RELATIONSHIP BETWEEN SPHENOID SINUS VOLUME AND PROTRUSION OF NEUROVASCULAR STRUCTURES

One pioneering findings from the current study is the relationship between ON and ICA protrusion and sphenoid sinuses volume. Previous researches had concentrating on the probable associations between protrusion of neurovascular structures into the sphenoid sinuses and variations of pneumatization types. Recently, a number of investigators have evaluated the possibility of relationships between distinctive anatomical variations and protrusion of neurovascular structures into cavity of the sphenoid sinuses: for more detail, Rahmati et al. (2016, p.32) reported a significant association between the pneumatization of anterior clinoid and pterygoid processes and ON protrusion. as well, ICA protrusion was significantly correlated with the pneumatization of pterygoid process.

Moreover, study done by Štoković et al. (2016, pp.96-76) stated that, neurovascular protrusions were correlated with sellar and postsellar pneumatization. The same result was reported by Dal Secchi et al.(2018, pp. 161–166), ICA protrusion was positively correlated with extension of pneumatization posteriorly in the Sphenoid sins .These results are agreeing with our findings.

In contrast, Gibelli et al. (2019, pp. 507–512)found a significant correlation between ICA alone and simultaneous ICA and ON protrusion with bigger sinuses, while separated ON protrusion was not related to sinus volume.

In this study, we have investigated the relationship between the frequency of neurovascular structure protrusion and volumes of sphenoid sinus. The result showed that there a difference between the prevalence of ON protrusion and volumes of SS. There was no significant association between ICA protrusion and sinus volume. Moreover, we found volume of sphenoid sinus was larger in sellar and postsellar type respectively. As ON protrusion was statistically significant with sinus volume, by means more in sellar and post sellar pneumatization.

From a surgical view point, this result is of grand attention: in actual fact, whereas in cases of extended pneumatization of sphenoid sinuses we should expect a protrusion of ON. In the other hands, ICA protrusion is more deceiving than ON protrusion, and should be well evaluated in all cases, impartially from the volume of sphenoid sinuses.

5.3 INTER OPTIC AND INTER CAROTID DISTANCE

The distance between optic nerves has been measured by several studies. In all previous researches they have used dry human skulls. To our information, this is the first study which measured the distance between intracranial parts of optic nerves by using hypophyseal MRI scans.

A study conducted by Bergland et al(.1968)examined 225 human autopsy. They reported smallest interoptic nerve distance at the level of optic foramen was of 13 mm, differing from 8 to 20 mm (Bergland etal .1968, pp. 93–99).

Similarly, a research was made on 20 cadaveric samplings by Slavin et al. (1994, pp. 136–144). They measured the interoptic nerve distance as the distance between centers of ONs, it was ranged from 18to23mm at the level of Intracranial Opening of the Optic Canal. The same, study was done by Jho & Ha (2004, pp. 1–8), Six cadaver head specimens were studied. The reported interoptic nerve distance at the intracranial opening of the optic canal was 18 mm (varying between 15 and 22 mm). Also, the measured interoptic distance by Kanellopoulou et al.(2017, pp. 665–676) was 16.9±2.5 mm.

In the present study, inter optic nerve distance (IOND) was measured at two points. IOND1 defined as the distance between intracranial part of ON just after coming from optic foramen. While, IOND2 defined as the distance between intracranial prechiasmatic suprasellar part of ON which lie superior to paraclinoid ICA. The mean IOND1 was 11.48±1.4mm, IOND2 was 7.0±1.2mm, there was no statistically difference between male and female. However, based on available literature we have no data to compare our finding with other studies.

Our measured distances were shorter than above mentioned studies, the explanation for this is: the intracranial ON runs medially backwards and slightly upwards within the subarachnoid space of the middle cranial fossa. They end by forming the optic chiasma in the floor of the third ventricle(Forrester et al. 2015). So, the distance it become shorter.

Table 5.6 below illustrates Inter ON Distance Among Previous Studies Compared to Present Study

Table 5.6: Inter ON distance among previous literature compared to present study

Study	Year	Place	Sample size	Specimen	IOD mm
Bergland et al	1968	USA	225	cadaver	8-20
Slavin et al	1994	USA	20	cadaver	18-23
Beretta et al	2005	USA	50	skull	14±1
Guthikonda et al	2010	USA	100	skull	19±2
Akture and Baskaya	2014	Turkey	25	skull	16-19
Kanellopoulou et al	2017	Greek	96	skull	16.9±2.5
Present study	2019	Turkey	204	MRI	11.48±1.4

IOD; Inter Optic Distance
MRI: Magnetic Resonance Imaging
Source: This table was prepared by Fatma Alfageih

On the same extends, inter carotid distance attracted the attention of many researchers. For example, Yilmazlar et al.(2008, PP.165-174) analyzed eighty-five sellar and parasellar tissue specimens fixed on formaldehyde taken from human cadaver, MRI scans of 28 macroadenoma patients and 22 healthy adults also were evaluated in this study, In cadaveric specimens, the reported intercarotid artery distances (cavernous part) were 17 ± mm anteriorly, 20 ± 4 mm medially, and 19 ± 4.6 mm posteriorly. Whereas in normal-sella images, the distances were 15.4 ± 2 mm anteriorly, 16 ± 3 mm medially, 16 ± 3.4 mm posteriorly.

Besides, the intercarotid distance measured by Hamid et al. (2008, pp. 9–15), using coronal MRI scan was 23mm(range12-30mm) (Hamid *et al.*, 2008).Our finding was not so different, the mean distance between cavernous parts of ICA was 20. 53±3mm.

Moreover, there was no much previous studies about the distance separating paraclinoid segments of ICA. a research paper done by Mascarella et al.(2015, pp. 195–201), measured the distance between different part of internal carotid artery amog 212 patients and 34 controls examined by CT and MRI scan. They found intercarotid distance at cavernous part was17.3mm (16.1-18.5), while at paraclinoid part was13.3mm (12.7-13.9) in control group. That was cross ponding to our measured distance, the PICD was13.6±1. 8mm.

Also, the difference between sex was insignificant for both inter carotid distance and inter optic distance. There was no previous data to compare with. For more details Table 5.7 below compare our findings wit previous literature, it was within the measured ranges.

Table 5.7: Demonstrate measures of inter carotid distance reported in various studies

Study	Year	Place	Sample size	CICD mm	PICD mm
Cavallo et al	2007	Italy	15 Cadavers	9 -24	-
Yilmazlar et al	2008	Turkey	94 cadavers 22 MRI	13-24	-
Mascarella et al	2015	Canada	212 cases and 43 control MRI	16.1-18.5	12.7-13.9
Farımaz et al	2019	Turkey	173 CT 49 MRI	13.6 ± 2.8	-
Present study	2019	Turkey	204 MRI	20±3	13.6±1.8

CICD: Cavernous Inter Carotid Distance
PICD: Paraclinoid Inter Carotid Distance
Source: This table was prepared by Fatma Alfageih

The most original results from the current study concern the association between ICD and IOD distance and sphenoid sinuses volume. The volume of the sphenoid sinus is an important factor and have a high regard for endonasal techniques. The larger sinus, recognition of bony protuberances and depressions in sinus wall will be easier and more comfortable. In conchal and presellar pneumatization, it is difficult to visualize most of the landmarks within the sinus cavity, that causes the removal of the planum and tuberculum more challenging. This explains to an increased risk of surgical trauma to the neurovascular structures of these cases. In patients with short distances between the optic nerves and the carotid arteries, admission to the suprasellar area is more limited and, as a result, possibly increased risk of complications. In this study the relationships between distance separating two optic nerves and carotid arteries as well and sinus volume was statistically significant. These are an important data for preoperative preparation to define the proper surgical approach.

6. CONCLUSION

In present study, we assessed the sphenoid sinus and it is related neurovascular structures. The mean volume of the sphenoid sinus was 23.4cc, which was a statistically significant difference between the gender as male gender (27.32cc) has a larger volume than female(21.24cc) gender. The result showed larger volume in our patients compared to other studies.

Sphenoid sinus with single septa was prominent among study population (61.8percent) and the principle attachment site of the septa was sella (40.2percent). The differences between gender was statistically nonsignificant.

The commonest types of pneumatization was the post sellar type 58.3percent, followed by sellar (36.8percent), presellar (4.9percent), conchal and a pneumatized were not seen. But the differences showed no statistically significance between gender and pneumatization types.

The majority of optic nerves were protruding 43.6percent, and non-protruded ON was seen in 40.7percent. There was significant relation between optic nerve protrusion and sinus volume. The ICA in relation to the sphenoid sinus was seen protruded in vast frequency 53.9percent, non-protruded ICA in 29.4percent of the study population. The relation between ICA protrusion and sinus volume was statistically nonsignificant.

The mean IOND1 was 11.84mm, IOND2 was 7mm. The distance between carotid artery was as follow, CICD 20.53mm, PCICD 13.72mm. the distance between optic nerves and the distance between carotid arteries was more in larger sphenoid sinus.

The advancement of the investigation techniques and minimally invasive procedures facilitate detailed study of the sphenoid sinus relation and variation in order to avoid iatrogenic serious complication.

This can be succeeded by fundamental recognition of basic anatomy and structural variations between individuals in a different population. Furthermore, sphenoid sinus is a crucial anatomical structure that entails expansion of the existing anatomical knowledge and following the latest anatomical variation classifications. In the clinical field, the sphenoid sinus variation of Turkish population is significantly necessary for neurosurgeons, otorhinologist, and radiologist. Similarly, this knowledge could take role in forensic medicine in the future

IMPACT

This study could assistance the neurosurgeon and otorhinolaryngologist by routine description of the sphenoid sinus and related neurovascular structures variations in the imaging report for FESS is highly recommended to decrease possible complication, and these variations could be useful in the future in forensic medicine.

LIMITATION OF THE STUDY

This research was conducted from data of hypophyseal MRI of patients whom had done for investigation purpose. Thus, the sample of healthy subjects is required if the result represents whole population is required. Likewise, there was no literature has used the MRI study different sphenoid sinus variations. Moreover, limited literature that measured the distance separating the carotid arteries. Also, there are no published studies about the distance between intracranial part of the optic nerve to compare our results with. Finally, our data collected from one hospital, in order to be the result more generalizable, a larger sample from different regions of Turkey are required.

RECOMMENDATION AND FUTURE WORK

A study of the sphenoid sinus variations on healthy individuals is recommended in order to represent the whole population. Hence some sphenoid sinus variations might be due to diseases. The prevalence of the variation among hospital population could differ from the prevalence in healthy population.

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