Original Article

Analysis of Optic Nerve Types in Relation to Posterior Paranasal Sinuses: A Computed Tomographic (CT) Study

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Abstract

Objective: To assess the variations in the course of optic nerve (ON) in relation to sphenoid sinus with the help of CT scan.
Methodology: A cross-sectional study was carried out using computed tomographic (CT) paranasal sinus scans of two hundred and seventy study participants between January 2017 and May 2017. Non-probability consecutive sampling technique was used and data was entered on SPSS version 23. Inclusion criteria comprised of adults coming for CT head and brain who did not have bony abnormality of sphenoid and ethmoid sinuses or adjacent structures. However, individuals with sinonasal tumors, chronic rhinosinusitis, prior sinus surgery, facial fracture, nasal polyposis and congenital craniofacial anomaly were excluded from this study. Analysis of optic nerve was carried out according to DeLano's classification.
Results: Type 1 ON was found to be the most frequent type; 55.93%, followed by type 2 with a frequency of 26.85%. However, type 3 and type 4 appeared less frequently, that is 11.1% and 6.11%, respectively. When comparing right and left sides it was noted that the frequency of type 1 optic nerve was found to be higher on both right and left sides with a value of 56.30% and 55.5%, respectively. Type 2 showed a frequency of 26.67% on right side and 27% on left side. Type 3 was identified to be 11.4% and 10.7% on right and left sides, respectively. Type 4 optic nerve was found to be the least common type in our study on both sides, i.e. 5.56% on the right side and 6.67% on the left side.
Conclusion: The combined percentage of type II and type III ON that is 37.96% in our sample brings us to this conclusion that fairly high percentage of our population is exposed to increased potential risk of iatrogenic optic nerve injury thus emphasising the need for careful evaluation of ON in relation to sphenoid sinus anatomy on CT scan prior to endoscopic sinus surgery.
Keywords: X-ray CT scan, optic nerve, ethmoid sinus, sphenoid sinus, paranasal sinuses.
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Introduction

Interest of surgeons in both the anatomy and pathophysiology of the paranasal sinus (PNS) has been stimulated due to advances in endoscopic sinus surgery (ESS). The ultimate aim of the surgeon is aerating the sinuses and restoring mucociliary clearance in order to restore the function of paranasal sinuses[1].

ESS is consistently gaining momentum in the treatment of sinus disease[2]. Visualisation and treatment of all sinus drainage passages is now possible on outpatient basis. Excellent mapping of the sinuses has been made possible by high resolution CT. It is also found to be helpful in reporting the extent of mucosal disease[3].

The normal anatomy and variations of sinus structure, as well as pathologic appearances and complications of sinus disease, needs to be well understood by the radiologist to provide optimal patient care.

The sphenoid bone shows high structural complexity. It is an unpaired bone of the neurocranium. It forms a component of the floor of middle cranial fossa, the orbital apex and also a part of the lateral wall of the skull. It resembles the shape of a butterfly with extended wings. It is composed of the body, the greater and lesser wings and the pterygoid

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plates. The development of the sphenoid sinus takes place in the body of sphenoid bone[4]. The floor of the middle cranial fossa is formed by the body of the sphenoid bone flanked by the greater wings on each side. The ossification centers of the sphenoid body are in close relationship with neurovascular-structures, for instance, the maxillary nerve, the optic nerve (ON), the internal carotid artery (ICA) and the vidian nerve. This explains their close relations to the sphenoid sinus.

As compared to other paranasal sinuses, sphenoid sinus follows a different developmental pattern. A recess appears at birth which is present between the pre-sphenoid body and the sphenoid concha. The development then begins posteriorly and inferiorly.

Throughout the second or third year of life, fusion of a part of sphenoid concha takes place with the pre-sphenoid, thus forming the cavity for sphenoid sinus. As a result, the pre-sphenoid recess becomes the sphenoethmoidal recess.Pneumatisation occurs after this stage in the pre-sphenoid and the basi-sphenoid of the sphenoid bone[5].

Although the definitive cavity forms at puberty, the actual sinus cavity starts becoming visible by the age of 8 to 10 years[6]. On the posterior nasal wall the origin of the sphenoid sinus can be clearly identified by the location of its ostium.

The anatomic relationships of the sphenoid sinus (SS), and neighboring structures are important to the otolaryngologist who performs sinus surgery and trans-septal or trans-sphenoidal pituitary surgery. Serious complications may occur because of the proximity of important structures with sphenoid sinus such as orbit, brain, cavernous sinus, and internal carotid artery (ICA). The optic nerve (ON) is at a particular risk, and postoperative blindness has been reported[7-9].

The sphenoidal sinus is a roughly octagonal structure, two of its sides face the nasal cavity and the rest are facing the endocranium. They are the posterior most among the paranasal air sinuses and is least accessible to surgeon. They are a pair of large irregular cavities within the body of sphenoid bone and lie posterior to the upper part of the nasal cavity. Its pneumatisation is variable and ranges from minimal to extensive[10]. The sinuses are minute cavities at birth, and their main development occurs after puberty. A septum usually separates the sinus which deviates from the midline in about 75% individuals and therefore, they become unequal in both size and form. Bony accessory septa may further partially divide their cavity. Occasionally, one sinus overlaps the other and rarely do they intercommunicate. Bony ridges may project into the sinuses from their lateral walls which are produced by the ICA, pterygoid canal and maxillary branch of trigeminal nerve[4-11]. Additionally, the projection of ON may also be observed in about 15% of individuals.

Sphenoidal sinus' superior wallis in continuity with the ethmoidal sinus' roof and it comes in direct contact with the optic chiasma, hypophysis cerebri and olfactory nerves at the floor of the anterior and middle cranial fossa. In the midline, the anterior wall is connected to the perpendicular plate of the ethmoidand vomer, and it is also connected to the lateral masses of the ethmoid on each side[12]. Sphenoid sinus ostium is often found on its anterior wall. This wall can be displaced by Onodi cells[13]. They are highly developed posterior ethmoid cells that begin pneumatising far laterally and to some degree superiorly to the sphenoid sinus. They are found to be intimately associated with the optic nerve. The sinus floor forms the dome of nasopharynx and choanae. The thin lateral walls are divided into two areas: anteriorly is the orbital zone and posteriorly is the cranial zone. Extremely important structures such as ICA, ON and the cavernous sinus are located adjacent to this wall.

One or both of the sinuses may partially encircle the optic canal[1,4]. The optic canal is the place where ON is least nourished in its course; therefore, it is very susceptible to injury through direct inflammatory invasion of the sinus[14].

Development of sophisticated technologies and instruments for endoscopic sinus surgery (ESS) has caused a dramatic increase in number of sinus surgeries performed. This is accompanied by an increase in malpractice lawsuits[15]. Over the past 20 years across the world, rhinology claims represented 70% of the total indemnity compensation for otolaryngology claims and ESS was the surgical procedure most often involved. One of the most common complications listed in ESS lawsuits is optic nerve and orbital injury leading to blindness[16,17].

Optic nerve holds an intimate anatomic relationship with the sphenoid and posterior ethmoid sinuses, because it generally passes adjacent to the superolateral aspect of SS. A highly pneumatised

SS may cause the ON to traverse freely through it[18-20], posing a risk of blindness if it is damaged during sinus surgery. Knowledge of this anatomy is a prerequisite in order to avoid direct injury to ON leading to devastating complication such as blindness.

Anatomical variations of posterior paranasal sinuses in our population may differ from other population and may be frequently encountered on routine CT examinations. Therefore, it is advisable that radiologists include these variations in their report. It is important for the surgeons to be aware of the relationship of optic nerve to the sphenoid sinus and the potential risks to this structure during ESS. Pre-operative CT reviews by endoscopic sinus and skull base surgeons may reduce surgical complications due to anatomic variations. Thus, information on normal anatomical variations in our population has clinical implications for safety of endoscopic sinus surgery.

The objective of the study was to assess the variations in the course of optic nerve according to DeLano's classification[16].

Subjects and Methods

Males and females between 21-60 years of age were included in this study. Individuals with sinonasal tumors, chronic rhinosinusitis, prior sinus surgery, facial fracture, nasal polyposis and congenital craniofacial anomaly were excluded. Study population comprised of adults coming for CT head and brain who did not have bony abnormality of sphenoid and ethmoid sinuses or adjacent structures. After approval from Ethics Review Committee of Ziauddin University, the study was carried out in the radiology department of Ziauddin University Hospital, Clifton, Karachi. Duration of study was from January 2017 to May 2017.

It was a cross-sectional study. Sampling technique used in this study was non-probability consecutive sampling. A sample size of two hundred and seventy (270) was calculated using OpenEpi calculator[21] keeping prevalence of variations of paranasal sinuses at 52%. CT scan of 270 individuals (540 sides) was performed on a 16 slice Toshiba Alexion in which the scanner's X-ray beam is rotated around the head and creates a series of images from different angles. Sequential axial images were obtained and processed to form volume data. From volume data multiplanar reconstructions were made in axial, coronal and sagittal planes. 3

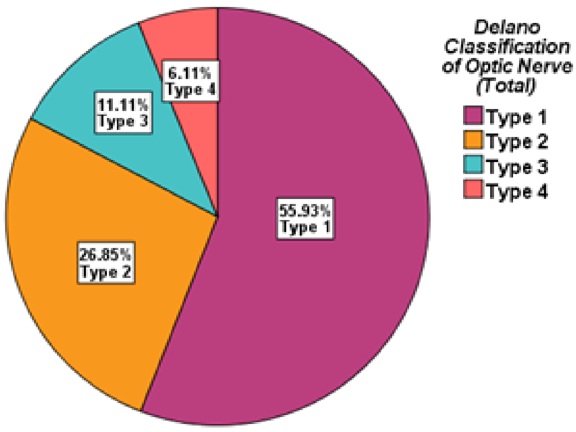

Fig 1. Pie chart showing the frequency of different types of optic nerve according to DeLano's classification

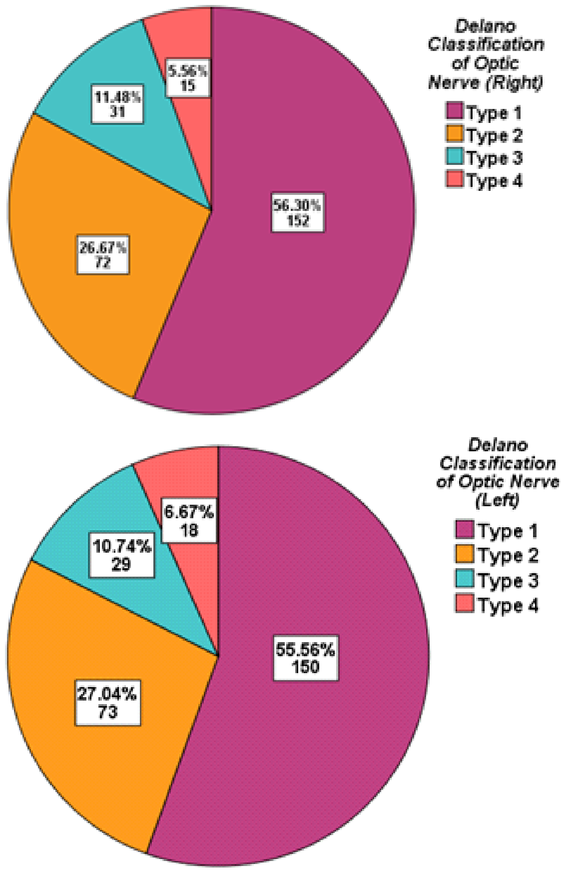

Fig 2. Pie chart showing the frequency of different types of optic nerve according to DeLano's classification on right and left sides

Table 1. Types of optic nerve (ON) according to DeLano's classification

ON Type	Description
1	Nerve courses directly adjacent to sphenoid sinus
2	Nerve causes indentation on sphenoid sinus wall
3	Nerve traverses through the sphenoid sinus
4	Nerve lies adjacent to sphenoid sinus and posterior ethmoidal air cells

dimensional volume rendered images in bone algorithm were also constructed. All images were evaluated in both coronal and axial planes. The coronal views of CT films were analysed in bony windows and the results were reported in a data sheet.

ON was assessed according to DeLano's classification shown in Table 1. DeLano, et al. in 1996 categorised the various relationships between the ON and posterior paranasal sinuses into four types as shown in Table 1[8,22-26].

The objective of this study is to assess the variations in the course of optic nerve according to DeLano's classification.

Results

The position of optic nerve in relation to SS was observed according to DeLano's classification. Analysis of 270 CT scans (540 sides) showed that type 1 optic nerve was the most frequent type (55.93%) followed by type 2 with a frequency of (26.85%). However, type 3 and type 4 appeared less frequently that is, 11.1% and 6.11%, respectively (Fig. 1).

The frequency of type 1 optic nerve was found to be higher on both right and left sides with a value of 56.30% and 55.5% respectively. Type 2 showed a frequency of 26.67% on right side and 27% on left side. Type 3 was identified to be 11.4% and 10.7% on right and left side, respectively. Type 4 optic nerve was found to be the least amongst all four types being 5.56% on the right side and 6.67% on the left side (Fig. 2).

Discussion

In-depth knowledge of the anatomical relationships of sphenoid sinus is fundamental for the success of endoscopic sinus surgeries and to avoid the possible intraoperative surgical complications. The communication between the surgeon and radiologist is important for interpretation of CT PNS scans to optimise patient treatment.

To the best of our knowledge, this is the first study from Pakistan focusing on the frequency of types of ON in relation to posterior paranasal sinuses. Although many international studies have documented the frequency of types of ON, it was observed that they were conducted on a smaller sample size as compared to our sample size (smaller sample size seemed to be one of the limitations of their studies).

The superolateral location of cranial nerve II (CN II) in close relation to the SS renders it vulnerable to iatrogenic injury during endoscopic sinus surgery and trans sphenoidal pituitary surgery. Indeed, blindness due to direct CN II injury is one of the most shattering complications of ESS.

Type 1 ON was found to be the most frequent in our population and this is similar to that documented by majority of previous researchers who have also reported it as the overall most frequent anatomical relationship of ON and sphenoid sinus[11,23-28]. However, Bra et al. in 2004 did a cadaveric study on 64 adult heads and documented type 1 ON to be the second most common type, i.e. 25.8%, in their study[18]. Although they used a modified DeLano classification for this cadaveric analysis.

Second most common type in our study is type 2 ON appearing with a frequency of 26.85%. Previous literature reports similar frequencies of this type1[1,23,24,26,28,29]. However, Heskova et al. reviewed 34 CT scans and reported type 3 ON to be the second most common configuration in their study with a frequency of 14.7%. A study done by Pra et al. in 2014 on 75 patients reported type 4 ON to be the second most common configuration. Batra et al. documented type 2 ON to be the most common in Korean population showing a frequency of 39.8%[18].

Type 3 ON appeared less frequently, 11.11% in our study. A similar pattern has been observed by few researchers[23,26-28]. On the contrary, some studies show a different configuration. Type 3 ON was observed to be the second highest, with a frequency of 23.5% in a study conducted by Heskova et al. on a European population in 2009. However, some studies report type 3 ON to be the least in their population with a frequency of 1.8%, 5.4% and 9.4%, respectively[11,24,29].

In our study, frequency of type 4 ON was the least that is 6.11%. A similar result is shown by few a studies[23,25,27,28]. Although, Type 4 ON was seen to be the second most common with a frequency of 9.3% in a study conducted by Pra et al. in 2014 on Thai population. In this study, Pra et al. reported an overall low frequency of type 2, 3 and 4 in their sample accounting to a total percentage of only 24%. Where as Type 4 ON ranks third according to some studies that is 2.6%, 12% and 7% respectively[11,26,29].

The reason for variations may be due to the difference in selection criteria of age groups and also the selection of subjects. Some studies selected patients with sinusitis and sinonasal disease where as some selected individuals below 20 years of age. Ethnicity also seems to be a contributing factor since genetic makeup varies in different ethnic groups among the same population.

Assessment of ON was also carried out for right and left sides seperately to see whether there was any difference in the distribution of different types of ON on the two sides. We found similar pattern of ON types on both sides which is in accordance with many studies[18,23,24].

Preoperative recognition of these variations by the radiologist may be beneficial so that the limits of dissection can be identified. Axial and coronal CT sections should always be obtained prior to any surgery in the sphenoid sinus area

Limitation of this study is that the data was collected from only one tertiary care hospital which did not cater to a wide range of population. Non-probability consecutive sampling technique was used which was also one of the limitations. Recommendations include that data be collected from different hospitals of the city using the probability sampling technique, thus ensuring the inclusion of a wide range of population.

Conclusion

DeLano et al. in 1996 documented a high potential risk of injury with type II and III ON[22]. These two types constitute 37.96% of our sample indicating an increased potential risk of injury of ON during ESS in our population.

CT examination is an ideal method for the detection of the bony variations of paranasal sinuses. It is essential in pre-operative planning to ensure the safety and efficiency of paranasal sinus surgery.

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Conflict of Interest

Authors have no conflict of interests and no grant/funding from any organisation for this study.

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