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Optic Nerve Canal Variations in Relation to Posterior Para Nasal Sinus In Indians: A Review-Based Classification Approach

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ABSTRACT

Background: The optic nerve canal (ONC), as it travels from the orbit to the cranial cavity, lies in close anatomical proximity to the Posterior paranasal sinus (PNS)—particularly the sphenoid and posterior ethmoid sinuses. This relationship is critical during functional endoscopic sinus surgery (FESS) and skull base procedures. Anatomical variations of the ONC can increase the risk of surgical complications such as optic nerve injury and potential vision loss. Despite the clinical importance, limited data exist on these variations in the Indian population, where ethnic and genetic diversity may influence cranial anatomy. Our study aims to classify variations of the optic nerve canal in relation to posterior PNS in Indian ethnics.

Methods: This review synthesizes findings from multiple computed tomography (CT)-based observational studies focusing on the ONC's course relative to posterior PNS in Indian subjects. The Delano classification system was used to categorize ONC types, and additional anatomical features such as bone dehiscence and anterior clinoid process pneumatization (PACP) were analysed.

Results: Among 300 optic nerve canals reviewed, Type I (no indentation/protrusion) was the most common (65.3%), followed by Type II (18.0%), Type III (9.6%), and Type IV (7.0%). Bone dehiscence was present in 7.3% of canals, most frequently in Type III (27.5%). PACP was found in 14.3%, most common in Type III (34.4%). ONC symmetry was observed in 91.25% of subjects, while asymmetry was noted in 8.75%.

Conclusion: This review emphasizes the need for detailed preoperative imaging and anatomical assessment in Indian patients undergoing sinus or skull base surgeries. The application of a simplified classification system based on CT imaging enhances surgical planning, helps to avoid optic nerve injury and contributes safer clinical outcomes.

Keywords: *Bone dehiscence, Computed tomography, Ethmoid sinus, Optic nerve canal, Paranasal sinuses, Pneumatization, Sphenoid sinus.*

1. INTRODUCTION

An important anatomical feature with optic nerve as it actions from the orbit to cranial cavity is the optic nerve canal (ONC). In endoscopic sinus and skull base operations, the structures in close proximity to the posterior PNS, particularly the sphenoid and posterior ethmoid sinusesmake it crucial for surgical interventions [1].Differences in anatomical course and relationships of ONC might predispose patients to severe effects, including optic nerve damage, which, if not sufficiently recognised preoperatively, can cause permanent vision loss [2].Many investigations on the morphological variation of the ONC among different ethnicities have revealed racial and ethnic differences in its location and relationship with surrounding structures[3,4]. These anatomical intricacies could be understood which is particularly important in the Indian environment, where major genetic variation and ethnic variance could influence the sinonasal and cranial base structure. Especially the sphenoid sinus, posterior PNSoften show strong pneumatisation patterns that could cause dehiscence or optic nerve protrusion into the sinus canal[5,6].These anatomical features raise the risk related to FESS, optic nerve decompression actions, and transsphenoidal operations. Therefore, classifying the alterations of the ONC related to these sinuses not only enhances anatomical knowledge but also helps to determine surgical risk and prepare the body before operation[7].This study aims to categorisedifferences of ONC to posterior PNSin Indian population, identify the normal anatomical variants and derive a simplified classification for clinical application.

2. MATERIALS AND METHODS

The research was directed in Department of Radio-Diagnosis on 150 patients for a period of 1 year from January 2024 to December 2024 during which 300 optic nerve canals were evaluated.The participants were patients who underwent PNSCT scans for suspected sinusitis. Patients with facial trauma and malignancies with potential to erode sinuses were excluded from the study.

Data Collection and Study Design

Studies relevant for this purpose were chosen depending on the following standards:

- Paranasal sinuses' evaluation with high-resolution CT imaging
- Optic nerve canal classification depending on their alignment with the sphenoid and posterior ethmoid sinuses.
- Give Indian themes or statistics relevant to the Indian ethnic population top priority.

With sample counts of 150 individuals, these investigations comprised both prospective and retrospective observational approaches. The study was performed using Toshiba Aquilion Prime 160 slicer CT scanner. Thin 0.5 mm slice thickness were preferred.

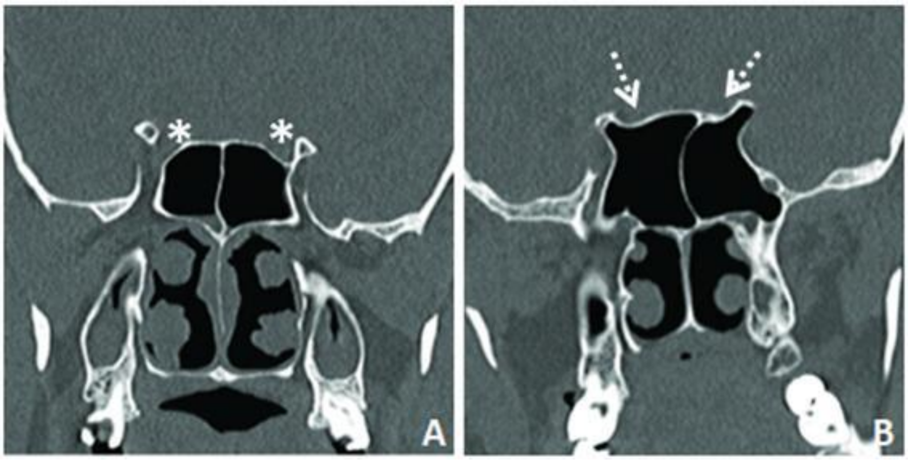
Imaging and Analysis

Bone window settings allowed standard coronal and axial planes of CT imaging. Imaging findings in respect to the posterior PNSand its relationship with the optic nerve canals were evaluated [8]. Anatomical viewing was enhanced using multiplanar reconstructions. Each form of ONC was reported using descriptive data including means and percentages[9].

Classification System

The ONC were categorized into four types based on Delano classification as shown in the figure 1

This study additionally assessed supplementary anatomical risk factors, including bone dehiscence of the canal and pneumatization of the anterior clinoid process (ACP), which may elevate the risk of optic nerve injury after sinus surgery.



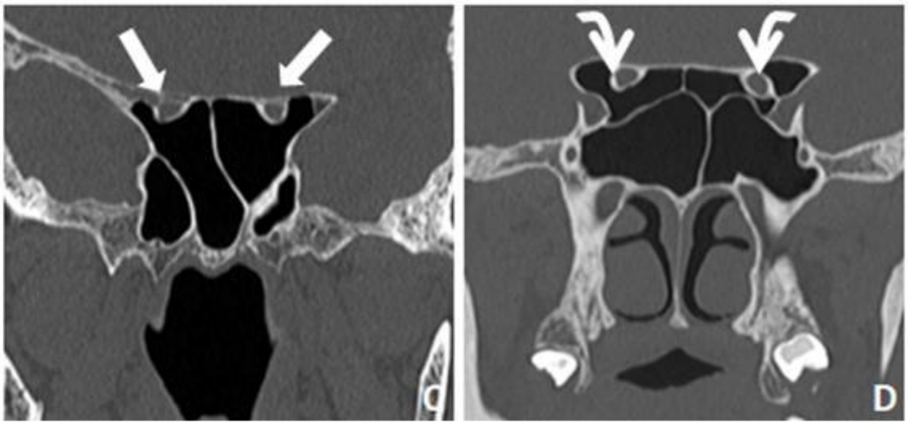


Figure 1 shows four types optic nerve canal based on Delano classification. A: Type 1 optic nerve canal with no contact or indentation on the sinus wall (Asterisks). B: Type 2 with partial indentation (<50%) into the sphenoid sinus (Dotted arrows). C: Type 3 with significant protrusion (>50%) into the sinus cavity (Solid arrows). D: Type 4 with close association with the posterior ethmoid sinus or Onodi cell (Curved arrows).

3. RESULTS

This review analysed ONC variations to Posterior PNS—specifically the sphenoid and posterior ethmoid sinuses—based on computed tomography (CT) imaging data from multiple Indian individuals. The findings are synthesized to highlight the frequency of each anatomical variant, side-wise distribution, demographic association and their clinical relevance.

Majority of subjects in study were male comprising 65% (n=98) of total study populationand remaining 52 were female participants contributing 35% of the total population. Male to female sex ratio in the study was 1.9:1. Among 150 patients in this study most of subjects were between age group 20 and 39 years comprising 30% (n=45) of the total study population. Second common age group in the study was between 40 and 59 years contributing to 26% (n=40) of total population.

The present study found that out of 300 optic canals assessed 196 (65.3%) were Type I which was the most common type in which the optic nerve neither indents nor protrudes into the sphenoid sinus. Among 196 type I ONC, 101 were on right and 95 were on left side. The second most often occurring was type II, which displays minor indentation. 18.0% (n=54) of optic nerve canal. Out of 54 type II ONC, 26 were on the right and 28 were on left. Type III (n=29; 9.6%) is third most common in which the nerve clearly extends into sinus. Among 29 type III ONC, 14 were seen on right and 15 were on the left side. Type IV (n=21; 7.0%) was the least common with nine on the right and 21 on the left side. Type IV is defined by its relationship with an Onodi cell or posterior ethmoid sinus. This distribution shows that although most patients have low-risk ONC types (Type I), a noteworthy fraction have anatomical differences that might raise surgical risk.

Bone dehiscence indicates lack of bony wall that protect optic nerve canal. Among 300 optic canals, 22 (7.3%) displayed bony dehiscence and 43 (14.3%) indicated PACP. On assessing the interactions among ONC types, bone dehiscence (lack of the bony wall protecting the nerve), and pneumatisation of the anterior clinoid process (PACP) we have noted that type III canals exhibited the greatest rates of PACP (34.4%) and bone dehiscence (27.5%). Type I had the lowest frequency of both risk variables; Type II and Type IV displayed modest risk. Type III optic nerve canal has significant risk of optic nerve damage after surgery followed by type II & IV. Type I has least risk of optic nerve damage during surgery.

Asymmetry was discovered in 8.75%, stressing the need of evaluating both sides separately. ONC symmetry was seen in 91.25% of instances, demonstrating bilateral similarity in most individuals. Among the 300 optic nerve assessed, 219 were asymmetric in distribution and remaining 21 were symmetric.

Table 1: Distribution of ONC Types

Type of ONC	Right	Left	Total	Percentage
I	101	95	196	65.3%
II	26	28	54	18.0%
III	14	15	29	9.6%
IV	9	12	21	7%

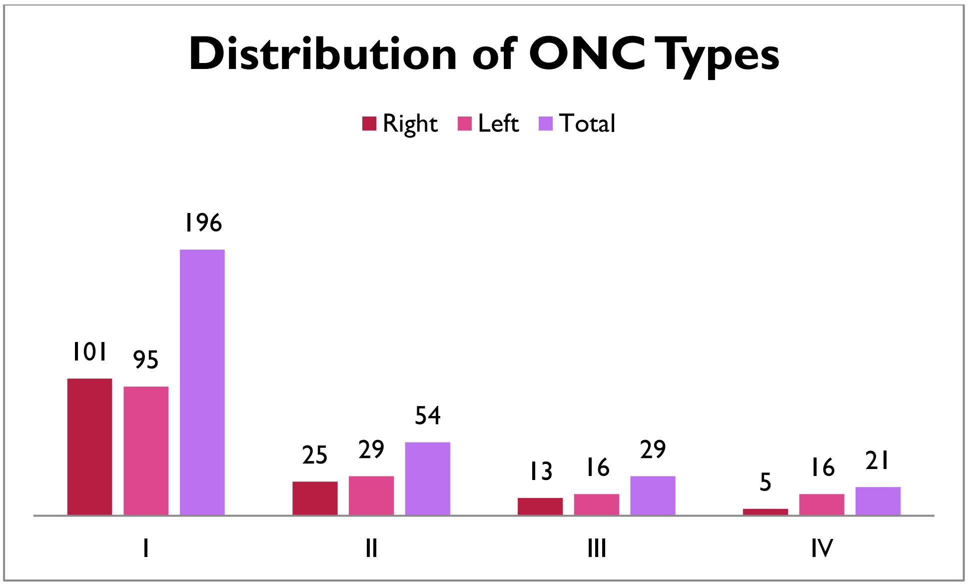


Figure 1 : DISTRIBUTION OF ONC TYPES

Table 2: Bone Dehiscence and Anterior Clinoid Process Pneumatization (PACP)

ONC Type	No. of Canals	Bone Dehiscence	% of Bone Dehiscence	PACP	% of PACP
I	196	7	3.5%	13	4.2%
II	54	4	7.4%	17	31.4%
III	29	8	27.5%	10	34.4%
IV	21	3	14.2%	3	15.7%
Total	300	22	7.3%	43	14.3%

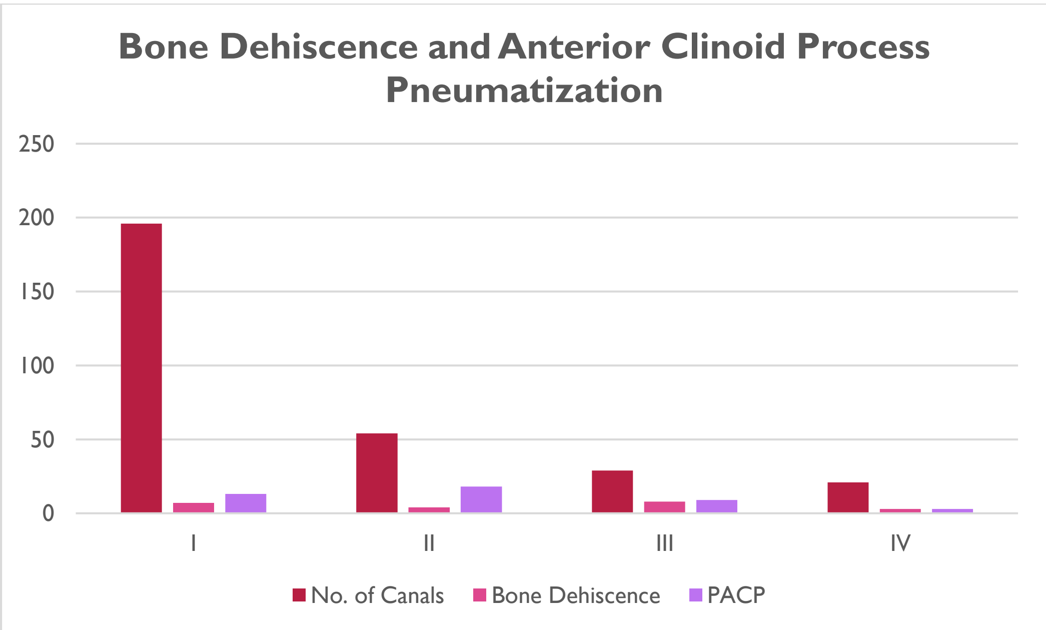


Figure 2 : Bone Dehiscence and Anterior Clinoid Process Pneumatization (PACP)

Table 3 : Distribution of ONC based on Symmetry

Type	No of Canals	Percentage
Symmetry	219	91.25
Asymmetry	21	8.75

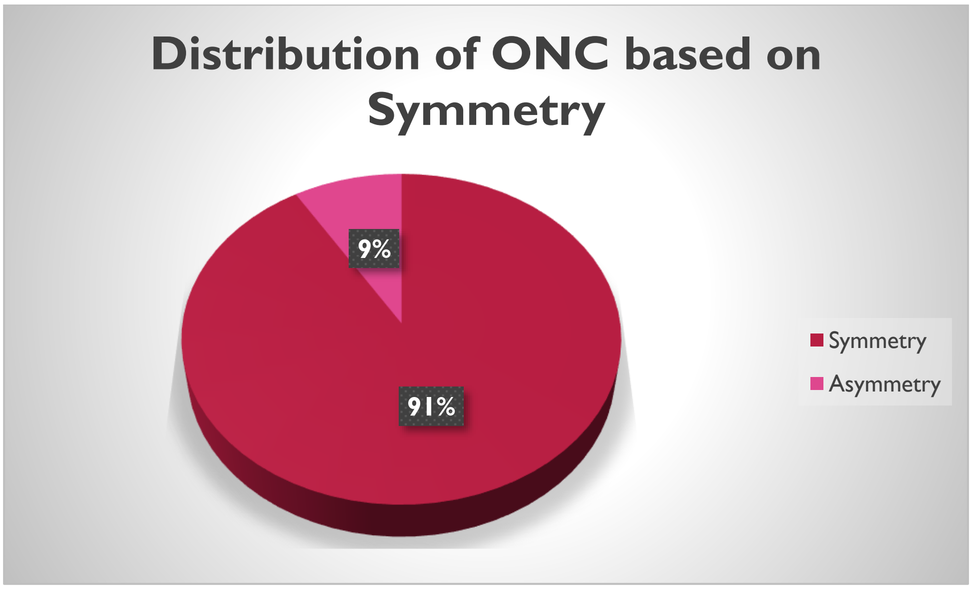


Figure 3 : Distribution of ONC based on Symmetry

4. DISCUSSION

The main structural differences of ONC in respect to posterior PNS in the Indian population highlighted in this study are consistent with past research including those by DeLano et al and Itagi et al. (60%) [8, 10]. In their study it was found that Type I ONC was the commonest occurring type. Type III had strongest correlation with bone dehiscence (27.5%) and anterior clinoid process pneumatization (34.74%) followed by Type II. Type II and III optic nerve canals majorly contributed to bone dehiscence and anterior clinoid process pneumatization indicating increasing surgical risk.

The observed results in this study align with Keerthi BP et alwho assessed sphenoid sinus pneumatization trends using CT imaging in a population from South India. Their research underlined how severe pneumatization, especially of the lateral and posterior sphenoid sinus walls may cause close contact, protrusion, or even dehiscence of surrounding neurovascular structures including the optic nerve [11]. These anatomical connections greatly raise the possibility of problems following endoscopic sinus and skull base operations. Their findings support the emphasis of the present research on the need of identifying high-risk ONC variants, especially Types III and IV through preoperative imaging since these are more likely to be linked with vulnerabilities connected with pneumatization. Including Indian-specific data into their study helps to support regional anatomical evaluations in surgical planning [12, 13].

Research from Hewaidi et aland Al-Rawi et alshow a greater incidence of Type IV canals, usually linked with Onodi cells, than worldwide statistics. The presence of bone dehiscence (7.3%) and PACP (14.3%) underlines even more the need of preoperative CT imaging for spotting high-risk anatomical variants. Over 91.25% of instances revealed symmetry in ONC forms. Rest of the 8.75% asymmetry emphasises the need of bilateral evaluation. These results confirm the requirement of region-specific anatomical knowledge to increase the safety of endoscopic and skull base operations in Indian patients [14,15].

This review-based study provides valuable insight into anatomical differences of the ONC to posterior PNS, with a focus on Indian population. The analysis of ONC types and associated anatomical risk factors such as bony dehiscence and anterior clinoid process pneumatization (PACP) revealed trends consistent with previous Indian studies, while also highlighting distinct differences compared to international data.

The most frequently observed ONC type in this study was Type I (65.3%), in which the optic nerve runs adjacent to sphenoid sinus without any protrusion. This distribution aligns with findings reported by Itagi et al(60%) and DeLano et al (76%), confirming Type I as the most common and least surgically hazardous configuration. However, Type II (18.0%) and Type III (9.6%), which involves increasing degrees of optic nerve protrusion into the sinus, were also present in a significant number of cases. These types are associated with a higher risk of optic nerve injury, especially during functional endoscopic sinus surgery (FESS) and transsphenoidal procedures [8,10].

The occurrence of Type IV (7.0%), which involves close association with the posterior ethmoid sinus or Onodi cells, is clinically important despite being the least common. This type is considered high-risk due to the proximity of optic nerve to ethmoidal air cells that may not be easily visualized without detailed imaging. In comparison, Devika et al and Ravindran et al reported a higher incidence of Type IV (21.78%), indicating possible regional or sample-related differences within the Indian demographic[16,17].

Regarding bony dehiscence, a total prevalence of 7.3% was observed, with the highest rates found in Type III canals (27.5%), followed by Type IV (14.2%). These findings support prior observations by Itagi et al and others, where advanced ONC types were shown to have reduced or absent bony protection, thereby increasing vulnerability to surgical trauma [10].

PACP was observed in 14.3% of the total canals, with particularly high rates in Type III (34.4%) and Type III(31.4%) variants. The presence of PACP is significant because it can shift the position and coverage of the optic nerve, complicating surgical approaches. These findings are in agreement with previous studies that associate PACP with increased anatomical complexity and surgical risk.

Symmetry in ONC configuration was noted in 91.25% of cases, suggesting bilateral consistency in most individuals. However, asymmetry was identified in 8.75% of subjects, which reinforces the need for comprehensive bilateral imaging. Even when clinical symptoms are unilateral, anatomical differences on the contralateral side may exist and must be accounted for in surgical planning.

5. CONCLUSION

The study emphasizes the critical importance of high-resolution CT imaging in identifying ONC variants, particularly Types II–IV, which are associated with increased risk during sinonasal and skull base surgeries. The findings affirm the utility of a simplified classification system and contribute valuable data for developing population-specific anatomical references. This is especially relevant in the Indian context, where unique craniofacial patterns may influence ONC morphology and clinical outcomes.

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