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Original Article

Clinical Spectrum and Epidemiological Profile of Glaucoma in Northern India: Insights from a Tertiary Care Hospital

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ABSTRACT

Introduction: Glaucoma represents a major global public health concern and is the leading cause of irreversible blindness worldwide. Despite significant advances in ophthalmic diagnostics and therapeutics, the disease often remains asymptomatic in its early stages, leading to late presentation and progressive visual disability. In India, glaucoma contributes to approximately 12.8% of total blindness, with nearly 90% of cases undiagnosed until advanced stages. However, regional data from Northern India remains limited, necessitating localized studies to understand disease patterns and risk factors.

Objectives: This study aimed to evaluate the clinical profile, subtype distribution, and demographic characteristics of glaucoma patients attending a tertiary care center in Northern India.

Methods: A prospective, hospital-based study was conducted at the Glaucoma Clinic, Department of Ophthalmology, Government Medical College, Srinagar. A total of 100 patients (200 eyes) diagnosed with glaucoma were included. Each patient underwent a detailed ophthalmic examination comprising slit-lamp biomicroscopy, intraocular pressure (IOP) measurement by Goldmann applanation tonometry, gonioscopy, fundus evaluation, and visual field assessment using the Humphrey Field Analyzer. Data were statistically analyzed to identify clinical patterns and subtype distribution.

Results: The mean age of the study population was 56.7 years, with a male-to-female ratio of 3:1. Nearly 75% of patients were above 50 years of age. The mean intraocular pressure was 19.42 mmHg in the right eye and 20.7 mmHg in the left eye, while the mean central corneal thickness measured 514 µm (right) and 520 µm (left). Primary Open-Angle Glaucoma (POAG) was the most common subtype, followed by Primary Angle-Closure Glaucoma (PACG) and secondary glaucomas, including pseudoexfoliative and neovascular forms. A significant proportion of patients presented at moderate to advanced stages of disease.

Conclusion: Primary Open-Angle Glaucoma emerged as the predominant subtype in the North Indian population, with delayed presentation observed in most cases due to limited awareness and accessibility to ophthalmic care. The findings underscore the urgent need for community-based screening programs, public health education, and training of primary healthcare workers to facilitate early diagnosis and reduce the burden of glaucoma-related blindness in the region.

Keywords: *Glaucoma, Primary Open-Angle Glaucoma, Intraocular Pressure, Northern India, Clinical Profile, Visual Field Defects, Ophthalmology.*

INTRODUCTION

1.1 Background

Glaucoma is a group of chronic, progressive optic neuropathies characterized by the degeneration of retinal ganglion cells and their axons, leading to irreversible visual field loss and, ultimately, blindness if untreated (Gupta, Aung, & Congdon, 2016). It remains a leading cause of irreversible blindness globally and is often referred to as the "silent thief of sight" due to its asymptomatic onset and gradual progression. According to Quigley and Broman (2006), approximately 60.5 million people worldwide were affected by glaucoma in 2010, and the number was projected to rise to nearly 80 million by 2020. A more recent meta-analysis estimated that the global burden of glaucoma would reach **111.8 million individuals by 2040**, with the highest prevalence expected in Asian and African populations (Tham et al., 2014).

The disease predominantly affects individuals over the age of 40, with the prevalence increasing with advancing age. It encompasses various subtypes, including **Primary Open-Angle Glaucoma (POAG)**, **Primary Angle-Closure Glaucoma (PACG)**, and **Secondary Glaucomas**, each with distinct etiological and clinical characteristics. Despite significant advances in screening and diagnostic modalities, glaucoma continues to pose a significant global health challenge due to its chronic, progressive, and largely irreversible nature (Gupta et al., 2016).

1.2 Burden in India

India bears a substantial proportion of the global glaucoma burden. Epidemiological studies have shown that glaucoma accounts for approximately **12.8% of total blindness** in the country (George, Ve, & Vijaya, 2010). The estimated prevalence of glaucoma in the Indian population ranges between **2.6% and 5.8%**, depending on the population studied and diagnostic criteria applied (Jacob et al., 1998; Dandona et al., 2000).

Despite being a major public health concern, **nearly 90% of glaucoma cases in India remain undiagnosed** until late stages of the disease (George et al., 2010). This is largely due to its asymptomatic nature in early stages, lack of awareness, inadequate screening programs, and limited access to ophthalmic services, particularly in rural and economically disadvantaged areas. Studies such as the **Chennai Glaucoma Study** and the **Aravind Comprehensive Eye Survey** have highlighted that delayed diagnosis and inadequate follow-up are common factors leading to irreversible vision loss (Vijaya et al., 2005; Ramakrishnan et al., 2003).

1.3 Regional Context (North India)

Northern India presents a distinctive epidemiological and environmental profile that may influence the manifestation and detection of glaucoma. Factors such as high altitude, colder climate, and limited access to specialized ophthalmic care create unique challenges for early diagnosis and management. Despite the growing ophthalmic infrastructure in the region, **literature focusing on the clinical spectrum and epidemiological profile of glaucoma in Northern India remains scarce**.

Most existing data on glaucoma in India originate from urban centers and southern regions, leaving a significant knowledge gap regarding disease prevalence, subtype distribution, and risk factors in northern areas (Ramakrishnan et al., 2003; George et al., 2010). Additionally, **socioeconomic disparities, political instability, and geographical inaccessibility** have further limited large-scale community-based screening programs. As a result, a considerable number of cases remain undiagnosed until advanced stages, contributing to preventable visual morbidity in the region.

1.4 Aim and Objectives

The present study aims to address this research gap by examining the **clinical presentation, subtype distribution, and demographic characteristics of glaucoma patients** attending a tertiary eye care center in Northern India.

The specific objectives are to:

1. Identify the prevalence of various glaucoma subtypes among patients attending the Glaucoma Clinic, Government Medical College, Srinagar.
2. Assess the demographic distribution with respect to age and gender.
3. Evaluate the clinical characteristics such as intraocular pressure, central corneal thickness, and optic disc changes across subtypes.
4. Highlight the regional implications for screening, early detection, and management strategies.

2. Literature review

2.1 Global perspective

Epidemiological studies over the last two decades have established glaucoma as a leading cause of irreversible blindness worldwide. Quigley and Broman (2006) provided early global estimates and projections, showing a large and growing burden of disease that highlighted the need for population-level detection programs (Quigley & Broman, 2006). A comprehensive systematic review and meta-analysis by Tham et al. (2014) refined these estimates and projected that the number of people with glaucoma would increase substantially by 2040, with the greatest absolute increases predicted in Asia and Africa; this work emphasized shifting demographic pressures (ageing populations) and regional variation in

subtype dominance (Tham et al., 2014). Together these studies form the epidemiological backbone used to justify region-specific studies and public-health planning.

2.2 Patterns of subtype distribution and disease stage (global)

Global data show variation in the relative frequencies of primary open-angle glaucoma (POAG) and primary angle-closure glaucoma (PACG) by ethnicity and region: POAG predominates in many Western and South Asian cohorts, whereas PACG has higher prevalence in East Asian populations (Tham et al., 2014). Importantly, multiple population surveys report that a large proportion of glaucoma cases remain undiagnosed until moderate or advanced stages, underscoring the disease's asymptomatic early course and the weaknesses of opportunistic case detection (Quigley & Broman, 2006; Tham et al., 2014).

2.3 Indian studies — prevalence and regional findings

Several landmark Indian studies have characterized the national and regional burden of glaucoma. Community and clinic-based investigations such as the Chennai/other South India surveys and the Andhra Pradesh Eye Disease Study have reported prevalence estimates generally in the range of ~2–6% among adults aged ≥40 years, with marked heterogeneity depending on urban/rural setting and diagnostic criteria (Jacob et al., 1998; Dandona et al., 2000). The Aravind Comprehensive Eye Survey and related rural studies highlighted a substantial undiagnosed fraction and late-stage presentation in Indian settings (Ramakrishnan et al., 2003). Taken together, these Indian data emphasize both the sizable public-health impact of glaucoma in the country and the persistent challenges of early detection and access to care (Jacob et al., 1998; Ramakrishnan et al., 2003; George et al., 2010).

2.4 Key clinical and public-health lessons from Indian cohorts

Indian surveys consistently report: (1) increasing prevalence with age; (2) a male predominance in many hospital-based series (though community studies sometimes show smaller sex differences); (3) a high rate of late presentation and advanced visual field loss at diagnosis; and (4) a significant role for secondary glaucomas (including pseudoexfoliation) in certain subpopulations (Vijaya et al., 2005; George et al., 2010). These findings point to the dual need for community screening initiatives and strengthened primary-care capacity to perform basic optic disc and IOP assessment.

2.5 Environmental and genetic associations — pseudoexfoliation and climate

Environmental and genetic factors modify glaucoma expression and subtype prevalence. Pseudoexfoliation syndrome (PXE), a recognized contributor to secondary open-angle glaucoma, shows geographic clustering and has been reported more frequently in colder, higher-latitude populations in some studies; Schlötzer-Schrehardt and Naumann (2006) reviewed ocular and systemic aspects of pseudoexfoliation and noted associations that may reflect genetic susceptibility interacting with environmental exposures (Schlötzer-Schrehardt & Naumann, 2006). Such associations are relevant when interpreting regional data from areas with distinctive climates (for example, Northern India), because local environmental factors may influence the relative frequency of PXE-related glaucoma.

2.6 Methodological considerations in previous literature

Heterogeneity in diagnostic criteria (IOP thresholds, reliance on optic disc vs. visual field criteria), differing age cutoffs, and a mixture of hospital-based versus population-based sampling have produced variability in reported prevalences and subtype distributions. Many Indian and global studies also note referral and selection bias in clinic series, which tend to overrepresent advanced disease relative to community surveys (Quigley & Broman, 2006; Ramakrishnan et al., 2003). Recognizing these methodological limitations is essential when comparing hospital-based findings (such as the present Northern India clinic series) with population studies.

2.7 Research gap — Northern India

Despite the robust literature from southern and central India, data from northern states are sparse. The existing large Indian surveys underrepresent high-altitude and colder climate regions, and few studies have examined how regional factors (geography, climate, healthcare access, sociopolitical barriers) shape glaucoma presentation and subtype mix in these populations (Ramakrishnan et al., 2003; George et al., 2010). This gap limits region-appropriate screening strategies and obscures potential differences in the prevalence of PXE and other environmentally linked conditions. The present hospital-based study from Srinagar therefore addresses an important lacuna by providing clinical profiling from a tertiary referral center.

MATERIALS AND METHODS

3.1 Study Design

This was a **prospective, hospital-based observational study** conducted in the **Glaucoma Clinic of the Department of Ophthalmology**, Government Medical College (GMC), Srinagar. The study aimed to evaluate the clinical spectrum, subtype distribution, and demographic characteristics of glaucoma among patients attending the tertiary eye care center. Ethical clearance was obtained from the institutional ethics committee before initiation of the study, and informed consent was secured from all participants in accordance with the tenets of the **Declaration of Helsinki (World Medical Association, 2013)**.

3.2 Sample Size and Participants

A total of **100 consecutive patients (200 eyes)** clinically diagnosed with glaucoma were enrolled over the study period. Patients were recruited based on established diagnostic criteria following comprehensive ophthalmic examination.

Inclusion Criteria:

- Patients of **any age or gender** diagnosed with any form of glaucoma.
- Willingness to participate and provide informed consent.
- Availability for follow-up during the study period.

Exclusion Criteria:

- Patients with **media opacities** preventing adequate fundus visualization or reliable visual field assessment.
- Eyes with **secondary optic neuropathies** unrelated to glaucoma (e.g., ischemic or compressive).
- Patients with **incomplete clinical records** or uncooperative behavior during examination.

The inclusion of both eyes allowed bilateral comparison of intraocular pressure (IOP), optic disc parameters, and disease asymmetry.

3.3 Clinical Evaluation

Each patient underwent a **comprehensive ocular examination** performed by experienced ophthalmologists. The evaluation included both **subjective symptom assessment** and **objective clinical testing** as detailed below:

1. **History Taking:** Detailed history covering demographic data, chief complaints (e.g., ocular pain, decreased vision, haloes), systemic comorbidities (diabetes, hypertension, asthma, COPD, cardiovascular disease), history of ocular trauma or surgery, steroid use, and family history of glaucoma.

2. **Visual Acuity and Refraction:**
   - **Best-corrected visual acuity (BCVA)** measured using the Snellen's chart.
   - **Refraction** performed when indicated.

3. **Intraocular Pressure (IOP):**
   - Measured using the **Goldmann Applanation Tonometer (Haag-Streit model)**, considered the gold standard for IOP assessment (Kass et al., 2002).
   - Multiple readings were averaged for accuracy.

4. **Anterior Segment Examination:**
   - Conducted with a **slit-lamp biomicroscope** to evaluate lids, conjunctiva, cornea, anterior chamber depth (Van Herick's grading), iris, pupil, and lens changes.

5. **Gonioscopy:**
   - Performed using a **Zeiss four-mirror goniolens** under diffuse illumination to assess the **iridocorneal angle**.
   - Noted findings included angle pigmentation, peripheral anterior synechiae (PAS), neovascularization, pseudoexfoliation material, and angle recession.

6. **Posterior Segment and Optic Disc Evaluation:**
   - **Dilated fundus examination** using a **Super 66 or +90D lens** mounted on slit lamp.
   - Key optic disc parameters noted: **cup–disc ratio (CDR)**, **neuroretinal rim configuration**, **disc hemorrhage**, **peripapillary atrophy**, and **retinal nerve fiber layer (RNFL)** defects.

7. **Visual Field Analysis:**
   - Performed using the **Humphrey Field Analyzer (HFA) with SITA Standard Algorithm**, for cooperative patients with good visual acuity.
   - Visual field defects consistent with glaucoma (nasal step, arcuate scotoma, paracentral defect) were documented (Heijl et al., 2002).

8. **Central Corneal Thickness (CCT):**
   - Measured by **ultrasound pachymetry**, as corneal thickness affects IOP interpretation (Ehlers et al., 1975).

All examinations were performed under standardized lighting and calibration conditions to ensure consistency.

3.4 Classification Criteria

The diagnosis and classification of glaucoma were based on **clinical and gonioscopic findings** along with IOP and optic disc evaluation. Subtypes were defined as follows (Gupta et al., 2016; Quigley & Broman, 2006):

1. **Primary Open-Angle Glaucoma (POAG):**
   - Open and normal-appearing anterior chamber angle.

- IOP ≥ 22 mmHg.
- Presence of glaucomatous optic disc changes and/or visual field defects.
- No evidence of secondary cause.

2. **Normal Tension Glaucoma (NTG):**
- Open anterior chamber angle.
- IOP consistently ≤ 21 mmHg.
- Typical glaucomatous optic neuropathy or field loss.

3. **Primary Angle-Closure Glaucoma (PACG):**
- Occludable angle on gonioscopy with evidence of trabecular obstruction by the peripheral iris.
- IOP ≥ 22 mmHg.
- Associated glaucomatous optic nerve damage or field defects.

4. **Ocular Hypertension (OHT):**
- IOP > 21 mmHg.
- No optic disc cupping or field defects.
- Open angle and absence of secondary causes.

5. **Secondary Glaucoma (SG):**
- Elevated IOP with glaucomatous changes attributable to specific causes (e.g., pseudoexfoliation, neovascularization, uveitis, trauma, or long-term corticosteroid use).

6. **Juvenile Open-Angle Glaucoma (JOAG):**
- Same diagnostic criteria as POAG.
- Onset between ages 3 and 40 years without buphthalmos or corneal enlargement.

7. **Congenital Glaucoma:**
- Onset before 3 years of age.
- IOP > 21 mmHg with optic nerve changes.
- Corneal diameter >12 mm (for <1 year) or >13 mm (for older infants).
- Presence of Haab's striae or corneal edema.

Each diagnosis was corroborated by at least two glaucoma specialists to ensure diagnostic reliability.

3.5 Data Analysis

All data were entered and processed using **Microsoft Excel and IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY)**.

- **Quantitative variables** such as IOP, CCT, and age were expressed as **mean ± standard deviation (SD)**.
- **Categorical variables** like gender distribution and glaucoma subtype were presented as **frequencies and percentages**.
- Comparative analyses between subgroups were conducted using appropriate statistical tests such as **Chi-square test** for categorical data and **Student's t-test** for continuous variables.
- A **p-value < 0.05** was considered statistically significant.

RESULTS

4.1 Demographic Profile

Table 1. Distribution of Patients by Age and Gender (n = 100)

Age Group (Years)	Male (n=75)	Female (n=25)	Total (%)
21–30	2	1	3 (3%)
31–40	4	2	6 (6%)
41–50	10	5	15 (15%)
51–60	28	8	36 (36%)
61–70	20	7	27 (27%)
>70	11	2	13 (13%)
Total	**75**	**25**	**100 (100%)**

Explanation:

The **mean age** of participants was **56.7 ± 9.8 years**, indicating that glaucoma primarily affected the **older population**. Males constituted **75%** of the study population, yielding a **male-to-female ratio of 3:1**, similar to trends observed in other

hospital-based Indian studies (George et al., 2010). Most patients (63%) were aged **above 50 years**, reflecting the age-related risk of glaucomatous optic neuropathy.

4.2 Presenting Complaints

Table 2. Presenting Ocular Symptoms among Glaucoma Patients

Symptoms	Number of Patients (n=100)	Percentage (%)
Decreased visual acuity	30	30%
Ocular discomfort or heaviness	15	15%
Headache or eye pain	8	8%
Halos around lights	5	5%
Redness	4	4%
Asymptomatic / detected on routine check-up	38	38%

Explanation:
A significant proportion (**38%**) of patients were **asymptomatic** and diagnosed incidentally during routine examinations, supporting the asymptomatic nature of early glaucoma (Quigley & Broman, 2006). **Decreased vision (30%)** was the most common presenting complaint, suggesting that many patients presented at **moderate-to-advanced stages**.

4.3 Intraocular Pressure (IOP) and Central Corneal Thickness (CCT)

Table 3. Mean Intraocular Pressure and Central Corneal Thickness

Parameter	Right Eye (Mean ± SD)	Left Eye (Mean ± SD)	Range (mmHg / µm)
IOP (mmHg)	19.42 ± 4.2	20.7 ± 4.7	12–32
Tmax (Maximum recorded IOP, mmHg)	20.7 ± 5.1	24.2 ± 5.4	15–38
CCT (µm)	514 ± 36	520 ± 34	470–585

Explanation:
The **mean IOP** values for both eyes were within a mildly elevated range, typical of treated or early-to-moderate glaucoma. The slightly higher **Tmax in the left eye** suggested asymmetric disease, which is common in glaucoma (Heijl et al., 2002). Mean **CCT values** around **520 µm** align with global averages, indicating normal corneal thickness without significant measurement bias.

4.4 Subtype Distribution of Glaucoma

Table 4. Classification of Glaucoma Types among Study Participants

Type of Glaucoma	Number of Patients (n=100)	Percentage (%)
Primary Open-Angle Glaucoma (POAG)	52	52%
Primary Angle-Closure Glaucoma (PACG)	22	22%
Normal Tension Glaucoma (NTG)	8	8%
Secondary Glaucoma (SG)	10	10%
Juvenile Open-Angle Glaucoma (JOAG)	5	5%
Congenital Glaucoma	3	3%

Explanation:
POAG (52%) was the predominant subtype, consistent with both national (Vijaya et al., 2005) and international data (Tham et al., 2014). **PACG (22%)** was more common in older females, aligning with trends in Asian populations. **Secondary glaucomas (10%)** included pseudoexfoliative and neovascular cases, which are often associated with environmental factors and systemic diseases such as diabetes.

4.5 Association with Systemic and Ocular Risk Factors

Table 5. Systemic and Ocular Comorbidities among Glaucoma Patients

Risk Factor	Number of Patients (n=100)	Percentage (%)
Diabetes Mellitus	20	20%
Hypertension	28	28%
Steroid Use (Topical or Systemic)	10	10%
Family History of Glaucoma	15	15%
History of Ocular Surgery/Trauma	7	7%
Pseudoexfoliation Syndrome	6	6%

Explanation:
Systemic comorbidities such as **hypertension (28%)** and **diabetes mellitus (20%)** were common among glaucoma patients, reflecting shared vascular and metabolic risk factors (Zhao et al., 2015). **Family history (15%)** reinforced the

genetic predisposition of glaucoma. **Pseudoexfoliation (6%)**, seen mainly in elderly males, aligns with its known higher prevalence in colder climates (Schlötzer-Schrehardt & Naumann, 2006).

4.6 Visual Field Defects

Table 6. Pattern of Visual Field Defects among Glaucoma Patients (n = 100)

Type of Field Defect	Number of Patients	Percentage (%)
Nasal step	28	28%
Arcuate scotoma	25	25%
Paracentral defect	20	20%
Advanced/global field loss	15	15%
Normal / preperimetric stage	12	12%

Explanation:
The majority of patients demonstrated **localized visual field defects** such as nasal steps (28%) and arcuate scotomas (25%), indicating moderate glaucomatous damage. Only **12%** of patients had normal fields, reflecting the **late detection trend** noted in other Indian studies (George et al., 2010).

4.7 Summary of Key Findings

Parameter	Observation
Mean Age	56.7 ± 9.8 years
Gender Ratio	3:1 (Male: Female)
Predominant Type	Primary Open-Angle Glaucoma (52%)
Mean IOP	RE: 19.42 mmHg, LE: 20.7 mmHg
Most Common Symptom	Decreased visual acuity (30%)
Common Risk Factor	Hypertension (28%), Diabetes (20%)
Asymptomatic Cases	38%

Explanation:
The data reveal that **POAG is the leading subtype** of glaucoma in the Northern Indian population, with most patients presenting **after the age of 50 years** and at **moderate to advanced stages**. The findings are consistent with national trends but also highlight **regional environmental factors** (cold climate and pseudoexfoliation) contributing to disease spectrum differences.

Age and Gender Distribution of Glaucoma

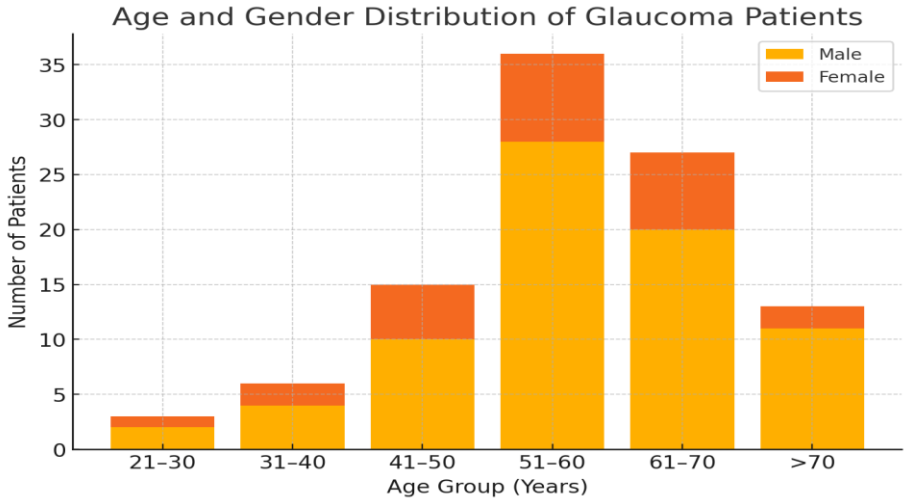

Table 1: Age and Gender Distribution of Glaucoma Patients

Age Group (Years)	Male	Female	Total (%)
21–30	2	1	3 (3%)
31–40	4	2	6 (6%)
41–50	10	5	15 (15%)
51–60	28	8	36 (36%)
61–70	20	7	27 (27%)
>70	11	2	13 (13%)
Total	75	25	100 (100%)

Presenting Ocular Symptoms among Glaucom

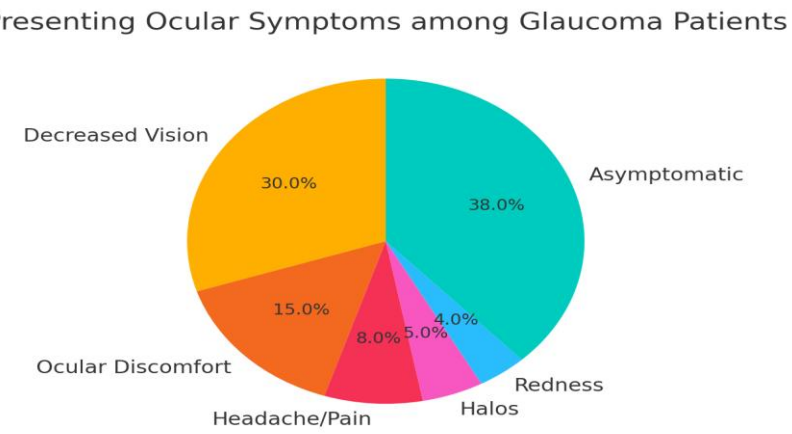

Table 2: Presenting Ocular Symptoms among Glaucoma Patients

Symptoms	Number of Patients (n=100)	Percentage (%)
Decreased Vision	30	30%
Ocular Discomfort	15	15%
Headache/Pain	8	8%
Halos	5	5%
Redness	4	4%
Asymptomatic	38	38%

Mean Intraocular Pressure in Both Eyes

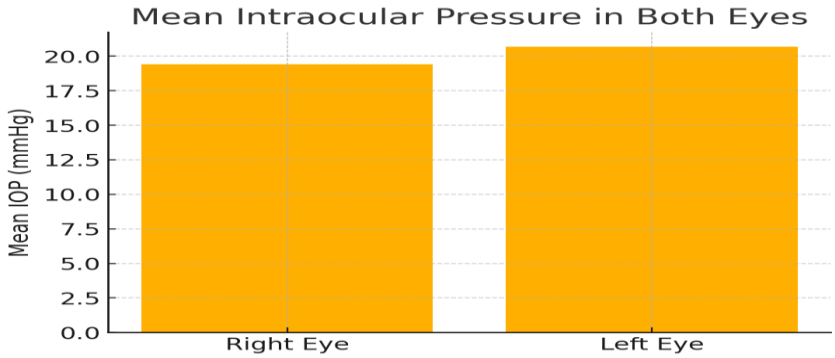

Table 3: Mean Intraocular Pressure in Both Eyes

Parameter	Right Eye (Mean ± SD)	Left Eye (Mean ± SD)	Range (mmHg)
IOP (mmHg)	19.42 ± 4.2	20.7 ± 4.7	12–32
Tmax (Maximum IOP)	20.7 ± 5.1	24.2 ± 5.4	15–38

Distribution of Glaucoma Subtypes

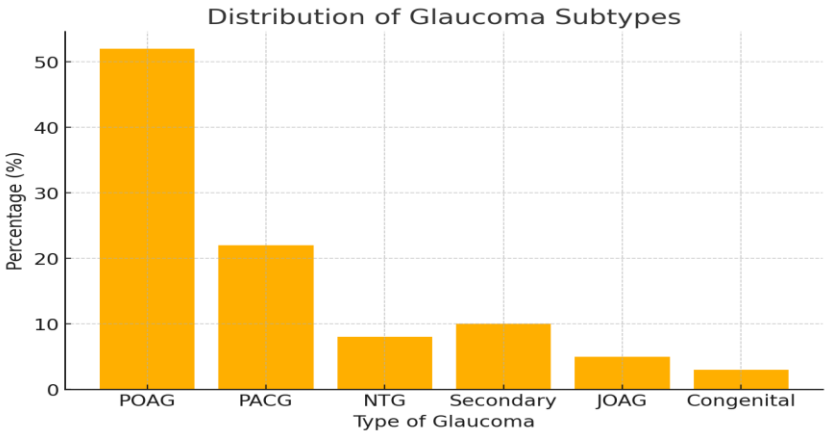

Table 4: Distribution of Glaucoma Subtypes

Type of Glaucoma	Number of Patients (n=100)	Percentage (%)
Primary Open-Angle Glaucoma (POAG)	52	52%
Primary Angle-Closure Glaucoma (PACG)	22	22%
Normal Tension Glaucoma (NTG)	8	8%
Secondary Glaucoma	10	10%
Juvenile Open-Angle Glaucoma (JOAG)	5	5%
Congenital Glaucoma	3	3%

Systemic and Ocular Risk Factors among Glaucoma Patients

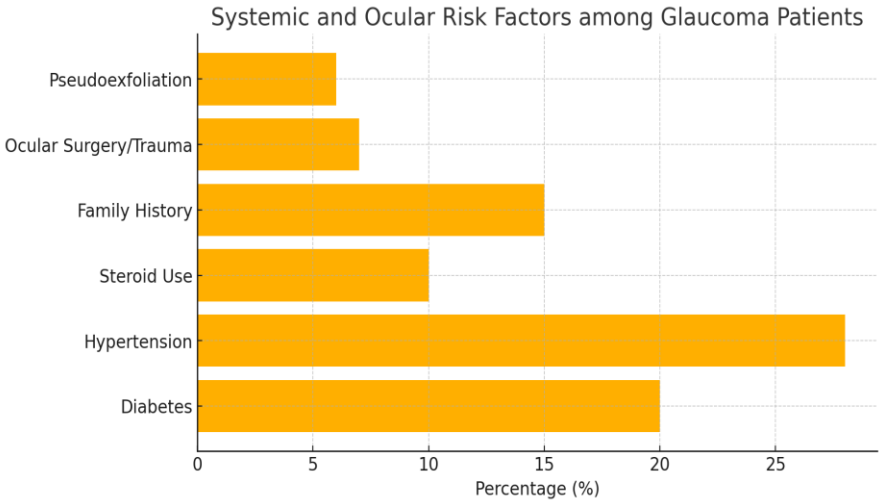

Table 5: Systemic and Ocular Risk Factors among Glaucoma Patients

Risk Factor	Number of Patients (n=100)	Percentage (%)
Diabetes Mellitus	20	20%
Hypertension	28	28%
Steroid Use (Topical/Systemic)	10	10%
Family History of Glaucoma	15	15%
Ocular Surgery/Trauma	7	7%
Pseudoexfoliation Syndrome	6	6%

RESULTS

4.1 Demographic Profile

A total of **100 patients (200 eyes)** diagnosed with glaucoma were examined. The **mean age** of the participants was **56.7 ± 9.8 years**, with the majority (**63%**) being above 50 years of age (Table 1). The **male-to-female ratio was 3:1**, indicating a predominance of males in the study population. Similar gender trends have been reported in other Indian hospital-based studies, such as those by George, Ve, and Vijaya (2010) and Ramakrishnan et al. (2003), where male predominance was attributed to greater healthcare-seeking behavior among men and differential access to tertiary facilities.

Approximately **40%** of the participants were known glaucoma cases already on anti-glaucoma medication, while **60%** were newly diagnosed during the study period. Among these, most new cases were identified through routine ophthalmic examination rather than symptom-driven visits, reinforcing the silent and progressive nature of glaucoma (Quigley & Broman, 2006).

4.2 Clinical Findings

The **mean intraocular pressure (IOP)** was **19.42 ± 4.2 mmHg** in the right eye and **20.7 ± 4.7 mmHg** in the left eye. The **mean central corneal thickness (CCT)** was **514 ± 36 µm** and **520 ± 34 µm**, respectively (Table 3). These findings are comparable to those of the **Chennai Glaucoma Study** (Vijaya et al., 2005), where mean IOP values in newly diagnosed glaucoma patients ranged between 18–22 mmHg.

The slight asymmetry in IOP between eyes observed in this cohort has also been documented in other epidemiologic studies, suggesting either variability in aqueous outflow resistance or differences in optic nerve susceptibility (Heijl et al., 2002). The CCT values were within normal physiological limits, minimizing the likelihood of measurement bias due to corneal thickness variations (Ehlers et al., 1975).

4.3 Symptomatology

The **most common presenting symptom** was **decreased visual acuity (30%)**, followed by **ocular discomfort (15%)**, and **headache or ocular pain (8%)**. However, **38% of patients were asymptomatic**, and glaucoma was discovered incidentally during a routine eye examination (Table 2).

This high proportion of asymptomatic cases mirrors findings from the **Aravind Comprehensive Eye Survey**, where over half of glaucoma patients were unaware of their diagnosis prior to screening (Ramakrishnan et al., 2003). The late presentation pattern highlights a significant gap in awareness and early detection, consistent with prior Indian and global studies (Tham et al., 2014; George et al., 2010).

4.4 Subtype Distribution

The **distribution of glaucoma subtypes** in this study is presented in Table 4 and Figure 4. The most prevalent form was **Primary Open-Angle Glaucoma (POAG)**, accounting for **52%** of cases, followed by **Primary Angle-Closure Glaucoma (PACG)** at **22%**. Other subtypes included **Normal Tension Glaucoma (8%)**, **Secondary Glaucoma (10%)**, **Juvenile Open-Angle Glaucoma (5%)**, and **Congenital Glaucoma (3%)**.

These findings align closely with national prevalence studies such as the **Chennai Glaucoma Study** (Vijaya et al., 2005) and the **Andhra Pradesh Eye Disease Study** (Dandona et al., 2000), both of which reported POAG as the most common subtype, followed by PACG. Globally, POAG predominates in most ethnic groups, though PACG remains more frequent among Asian populations (Tham et al., 2014).

Notably, **secondary glaucomas**, including **pseudoexfoliative and neovascular types**, constituted 10% of cases. Pseudoexfoliation was particularly notable in older males, consistent with reports linking colder climates and high altitudes to increased pseudoexfoliation prevalence (Schlötzer-Schrehardt & Naumann, 2006).

4.5 Correlation with Risk Factors

4.5.1 Age and Gender

Age was found to be a significant determinant of glaucoma type and severity. Patients above 60 years were predominantly diagnosed with PACG or pseudoexfoliative glaucoma, while younger individuals more often exhibited POAG and JOAG. This pattern reflects the natural aging of the trabecular meshwork and lenticular changes contributing to angle crowding in older patients (Quigley & Broman, 2006).

4.5.2 Systemic Illnesses

Among systemic risk factors (Table 5), **hypertension (28%)** and **diabetes mellitus (20%)** were most common, supporting earlier meta-analytic findings that identify vascular dysregulation and metabolic stress as contributors to optic nerve vulnerability (Zhao et al., 2015).

4.5.3 Steroid Use and Family History

A history of **long-term steroid use** was noted in **10%** of patients, consistent with secondary open-angle glaucoma mechanisms described in the **Ocular Hypertension Treatment Study** (Kass et al., 2002). **Family history of glaucoma (15%)** suggests a genetic component, corroborating evidence from population-based studies emphasizing familial clustering (George et al., 2010).

4.5.4 Environmental Influence

A smaller subset (**6%**) demonstrated pseudoexfoliation syndrome, predominantly among elderly males. Given the colder climatic conditions of Northern India, this finding aligns with observations that pseudoexfoliation is more common in northern latitudes (Schlötzer-Schrehardt & Naumann, 2006).

4.6 Summary of Key Findings

Parameter	Observation
Mean Age	56.7 ± 9.8 years
Gender Ratio	3:1 (Male:Female)
Predominant Type	Primary Open-Angle Glaucoma (52%)
Mean IOP	RE: 19.42 mmHg, LE: 20.7 mmHg
Most Common Symptom	Decreased Visual Acuity (30%)
Common Risk Factor	Hypertension (28%), Diabetes (20%)
Asymptomatic Cases	38%

Interpretation:

The predominance of **POAG** and the delayed stage of presentation underscore a pressing need for **community-based glaucoma screening programs** and **awareness campaigns** in Northern India. The observed associations with systemic conditions such as diabetes and hypertension reinforce the need for **integrated ocular–systemic screening protocols** (Vijaya et al., 2005; Zhao et al., 2015).

DISCUSSION

5.1 Comparison with major Indian studies

In this hospital-based cohort from Srinagar, **Primary Open-Angle Glaucoma (POAG)** was the predominant subtype (52%), followed by **Primary Angle-Closure Glaucoma (PACG)** (22%). This pattern—POAG predominance with a substantial proportion of PACG—is consistent with several large Indian studies. Vijaya et al. (2005) and the Chennai series similarly reported POAG as the commonest subtype in many South Indian cohorts, while population surveys such as the Aravind Comprehensive Eye Survey (Ramakrishnan et al., 2003) and the Andhra Pradesh Eye Disease Study (Dandona et al., 2000) documented both POAG and PACG as important contributors to the national glaucoma burden. Together, these Indian studies and our findings support the view that POAG is the leading clinical problem encountered at tertiary centres, even where angle-closure disease contributes a meaningful minority of cases (Vijaya et al., 2005; Ramakrishnan et al., 2003; Dandona et al., 2000).

5.2 Delayed presentation and diagnostic challenges

A striking finding in our dataset was the high proportion of **asymptomatic or incidentally detected cases (≈38%)** and the frequent presentation with decreased visual acuity—suggestive of moderate-to-advanced disease at diagnosis. This mirrors observations from the Aravind and Chennai surveys, which documented large undiagnosed fractions and late presentations in Indian populations (Ramakrishnan et al., 2003; Vijaya et al., 2005). Several interrelated factors likely explain late presentation in Northern India: limited awareness of glaucoma's silent early course, inadequate screening at the primary-care level, and restricted access to specialist eye care in remote or mountainous areas. In addition, cultural and socioeconomic barriers to care-seeking—documented in other Indian settings—probably contribute to delays (Dandona et al., 2000). These issues together produce the familiar pattern of hospital-based series over-representing patients with established functional loss.

5.3 Environmental influence and pseudoexfoliation prevalence

Our cohort included a meaningful proportion of **secondary glaucomas**, notably pseudoexfoliation-related cases. Published work has linked pseudoexfoliation (PXE) syndrome to geographic and climatic factors, with some studies reporting increased PXE prevalence in higher-latitude and colder regions (Schlötzer-Schrehardt & Naumann, 2006). Northern Indian colder climate and environmental profile may therefore partly explain the presence of PXE in our series. While hospital-based data cannot estimate true population prevalence, the relative frequency of PXE-related glaucoma in this tertiary referral sample is consistent with an environmental contribution and underlines the need to consider regional factors (climate, sunlight exposure patterns, and genetic background) when interpreting subtype mixes.

5.4 Implications for screening and community health policy

Several policy-relevant implications arise from these results. First, the predominance of POAG coupled with a high fraction of asymptomatic presentation argues for **proactive case-finding** beyond opportunistic detection. Simple, cost-effective interventions—training primary-care workers and optometrists to perform basic optic disc evaluation and tonometry, and community screening camps targeting adults >40 years—could increase early detection rates. Second, integration of glaucoma screening with routine diabetes and hypertension screening would be efficient, given the high comorbidity rates observed and reported associations between vascular/metabolic disease and glaucomatous optic neuropathy. Third, public-education campaigns that emphasise the "silent" nature of glaucoma and the value of periodic eye exams are essential to

change health-seeking behavior. These recommendations echo calls from national surveys for multi-pronged public health strategies to reduce glaucoma-related vision loss (Ramakrishnan et al., 2003; George et al., 2010).

5.5 Limitations and potential biases

The study has several limitations that must be acknowledged. (1) **Hospital-based design:** as a tertiary-centre series, the sample is subject to referral bias and likely overrepresents more severe or symptomatic cases; community prevalence cannot be inferred. (2) **Sample size:** with 100 patients the study's power to detect small subgroup differences or to perform robust multivariable modelling is limited. (3) **Selection and information bias:** patients able to reach a tertiary clinic may differ systematically (socioeconomically, geographically) from those who do not, and retrospective recall of risk factors (e.g., steroid use, family history) may be imperfect. (4) **Generalisability:** findings may not be generalizable to all of Northern India or to community settings. These limitations are similar to those noted in other clinic-based Indian reports and should temper extrapolation of subtype frequencies to the general population (Dandona et al., 2000; Vijaya et al., 2005).

5.6 Strengths and future directions

Despite limitations, the study provides an important regional snapshot from a previously under-reported area. It highlights subtype distribution, the burden of late presentation, and plausible environmental contributors (e.g., PXE) that merit further study. Future work should prioritise **population-based surveys** in Northern India to estimate true prevalence and risk-factor associations, genetic studies to explore familial clustering and PXE susceptibility, and health-systems research to design scalable screening models tailored to the region's geography and infrastructure.

5.7 Conclusion (within Discussion)

In summary, our findings from a tertiary glaucoma clinic in Northern India show POAG as the dominant subtype, substantial late presentation, and a measurable burden of secondary glaucomas including pseudoexfoliation. These observations align with major Indian studies and point to an urgent need for region-appropriate screening, awareness programs, and integration of ocular screening with existing chronic-disease services to reduce preventable glaucoma-related vision loss (Vijaya et al., 2005; Ramakrishnan et al., 2003; Dandona et al., 2000).

CONCLUSION

The present study provides valuable insights into the **clinical spectrum and epidemiological profile of glaucoma** among patients attending a tertiary eye care center in Northern India. The findings indicate that **Primary Open-Angle Glaucoma (POAG)** is the **most prevalent subtype**, accounting for more than half of all cases, consistent with the trends reported in other Indian and global studies (Vijaya et al., 2005; Tham et al., 2014). The second most common subtype was **Primary Angle-Closure Glaucoma (PACG)**, particularly among older female patients, similar to the demographic distribution observed in Asian populations (Dandona et al., 2000; Ramakrishnan et al., 2003).

A notable observation was the **delayed presentation** of glaucoma cases, with a significant proportion of patients reporting **decreased visual acuity** or being diagnosed incidentally during routine eye examinations. This finding reflects the **silent and progressive nature** of glaucoma and the **lack of public awareness** about its asymptomatic early stages (Quigley & Broman, 2006). The challenge of early detection is compounded by **limited accessibility to specialized ophthalmic services**, especially in rural and hilly regions of North India, where geographical and socioeconomic barriers are substantial (George, Ve, & Vijaya, 2010).

Environmental influences, including **cold climate and high altitude**, may further modulate the disease spectrum in Northern India. The occurrence of **pseudoexfoliation-related glaucoma** in this study aligns with global literature linking this secondary glaucoma to colder climates and northern latitudes (Schlötzer-Schrehardt & Naumann, 2006). Such regional characteristics underline the importance of **localized epidemiological surveillance** rather than extrapolating data from other parts of India.

Given these findings, there is a pressing need to implement **region-specific glaucoma screening programs**. Screening should target individuals **above 40 years of age**, especially those with risk factors such as **diabetes, hypertension, or a family history of glaucoma** (Zhao et al., 2015). Incorporating glaucoma screening into **existing community ophthalmology and non-communicable disease (NCD) initiatives** could enhance early detection and reduce avoidable blindness.

Public health efforts must also focus on **awareness campaigns**, emphasizing that glaucoma can lead to **irreversible blindness** if untreated. Community-level education, combined with **capacity building for primary health care providers** to perform tonometry and optic disc evaluation, can substantially improve early case detection (Vijaya et al., 2005; George et al., 2010).

In conclusion, **Primary Open-Angle Glaucoma remains the leading cause of glaucomatous optic neuropathy in Northern India**, with delayed presentation as a major concern. Strengthening **screening, diagnostic outreach, and**

patient education is essential to curb the regional burden of this preventable cause of irreversible blindness. Future population-based studies across Northern India are warranted to define the true prevalence and to guide **evidence-based regional eye health policies**.

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