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Title: A study of lens vault in primary angle closure glaucoma (PACG). The Central India Angle Closure Study.

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Introduction

The most common cause of irreversible global blindness is glaucoma. The global prevalence of glaucoma is 3.54% among the population aged 40–80 years[1]. Primary angle closure disease is more prevalent in Asian countries[2]. The angle-closure disease is characterized by an anatomical disorder where the iris comes into contact with the trabecular meshwork, hindering the normal drainage of aqueous fluid[3]. While pupillary block is considered to be an important mechanism suggested for the development of this condition, additional factors associated with the iris, lens, and ciliary body may also play significant role. The positioning and interplay of the iris and lens are crucial contributors to the onset of angle closure disease[4]. Numerous ocular factors that increase the risk of angle closure disease have been identified. These include a short axial length, shallow anterior chamber (AC), thicker peripheral iris, and anterior position of thick lens[5]. The introduction of anterior segment optical coherence tomography (AS-OCT) has revolutionized research by enabling comprehensive imaging of the anterior segment. This advancement allows for a more accurate assessment of angle, iris, and lens parameters. An example of such a parameter is lens vault (LV), which refers to the perpendicular distance between the anterior pole of the lens and a horizontal line connecting the temporal and nasal scleral spur. Measurement of the LV achievable through AS-OCT has demonstrated a relation to angle closure[6 7]. Assessing the quantitative aspects of anterior segment (AS) characteristics within these eyes could provide valuable insights into understanding the underlying causes of angle closure. Using swept source OCT, our study aims to measure the lens vault in eyes with primary angle closure glaucoma and identify its ocular association in Central India for which no data is previously available.

Methodology

It was a prospective hospital-based observational study. We had included 75 eyes of 43 patients with primary angle closed glaucoma. The subjects enrolled in this study were exclusively from Central India. Only eyes with primary angle closure glaucoma were included. Eyes on pilocarpine or those who had undergone any laser or surgical procedure were excluded.

All patients underwent a comprehensive assessment of the anterior segment (AS) using slit lamp examination, Goldmann applanation tonometry, and gonioscopy under low-light conditions, both with and without indentation. Indentation gonioscopy was conducted by a glaucoma specialist employing an Ocular Magna view-two mirror and Ocular four-mirror goniolens (Ocular instruments, Bellevue, WA USA) with a focused 1-mm light beam. Fundus and glaucoma evaluation was done with the 78-diopter lens and with a non-mydriatic fundus camera and SDOCT.

Swept-source OCT (Anterion® Heidelberg Engineering Inc, Heidelberg, Germany) was employed for ocular biometric measurements. This technique measured key parameters, including axial length, lens thickness (LT), lens vault (LV), aqueous depth (AQD), anterior chamber depth (ACD), angle opening distance (AOD), and trabecular iris space area (TISA).

Scans were focused on the pupil's centre and acquired along the horizontal and vertical axes utilizing the improved single protocol for anterior segment imaging. In-built software identified the position of the scleral spur in every image. The lead investigator subsequently confirmed image quality and the accurate localization of the scleral spur. Due to the often suboptimal quality and limited reproducibility of superior and inferior angle images[8], only angle parameters from the temporal and nasal regions were considered for analysis. The inbuilt software generated anterior segment and angle measurements.

1. Angle opening distance at 500 μ (AOD 500) is calculated as the perpendicular distance measured from the TM at 500 anterior to the scleral spur to the anterior iris surface[9].
2. Trabecular iris space area (TISA) is the trapezoidal area (referred to as TISA 500) demarcated by the AOD 500, the anterior surface of the iris, the inner corneoscleral wall, and the perpendicular distance between the scleral spur and the opposing iris[9].

3. Lens vault is the perpendicular distance between the anterior pole of the crystalline lens and a horizontal line joining the two scleral spurs[10].
4. Aqueous depth (AQD) is defined as the separation between the corneal endothelium and the anterior surface of the crystalline lens[11].
5. Anterior chamber depth (ACD) is measured as the space between the corneal epithelium and the anterior surface of the crystalline lens[11].

Statistical analysis

Statistical analysis was conducted utilizing SPSS software, version 20 (SPSS, Inc., Chicago, IL, USA). The statistical values and tests included mean and standard deviation. Parametric variables were analysed through bivariate analysis and multivariate analysis. P value of <0.05 was considered significant.

Results

75 eyes of 43 patients with a mean age of 58.43±8.42 years were analyzed. The mean LV was 0.93±0.25 mm, and the lens thickness (LT) was 4.83±0.33 mm (Table 1).
Bivariate analysis showed a significant correlation with IOP ($p = 0.002$; $r = 0.347$), LT ($p < 0.001$; $r = 0.583$), and a significant negative correlation with aqueous depth (AQD) ($p < 0.001$; $r = -0.549$), with angle opening distance at 500 µ nasal ($p = 0.001$; $r= -0.375$), angle opening distance at 500 µ temporal ($p < 0.001$; $r= -0.447$), respectively, and trabecular iris space area at 500µ nasal ($p = 0.002$; $r = -0.352$), trabecular iris space area at 500µ temporal ($p <0.001$; $r = -0.458$). No correlations were found with age, gender, spherical equivalent, and axial length.
Multivariate analysis with LV, as a dependent variable and IOP, AQD, AOD 500 and TISA 500 showed a significant correlation with IOP ($p = 0.015$) and AQD ($p < 0.001$).

Table 1: Demographic, clinical examination and ocular parameters in primary angle closure glaucoma (PACG).

Parameters	**PACG**
No of the patient (eyes)	43 (75)
Age (years), mean±SD.	58.43 ± 8.42 years
Female/male	37/38
IOP (mmHg), mean±SD	26.70 ± 15.59
Spherical equivalent	0.76 ±1.42
Axial length	22.64 ± 0.75 mm
AQD	2.05 ± 0.28 mm
Lens vault	0.93±0.25 mm
Lens thickness	4.83 ± 0.32 mm
AOD 500 nasal	0.05 ± 0.08 mm
AOD 500 Temporal	0.05 ± 0.08 mm
TISA 500 Nasal	0.01 ± 0.02 mm
TISA 500 Temporal	0.01 ± 0.02 mm

Discussion

This is a prospective observational study with the primary goal of identifying the role of lens vault in primary angle closure disease. This study found a significant association between lens vault (LV) and intraocular pressure (IOP) as well as aqueous depth (AQD), suggesting that LV could serve as a valuable clinical biomarker for primary angle-closure glaucoma (PACG). Extensive research has been conducted on the biometric features of eyes exhibiting narrow angles, focusing on Asian populations. Nongpiur et al.[10] explored the measurement of lens vault (LV) as a potential means to evaluate patients with angle closure, as they hypothesised that the position of the crystalline lens could be a factor in developing this condition.

In our study, the bivariate analysis revealed positive significant correlations with intraocular pressure and lens thickness (LT). Conversely, a significant negative correlation was found with aqueous depth (AQD), Van Herricks, angle opening distance at 500 μ, as well as trabecular iris space area at 500μ respectively.

Rivero et al.[12] in their study found a strong negative correlation between lens vault (LV) and anterior chamber depth (ACD) ($r = -0.80$, $p < 0.001$), axial length (AL) (r

= -0.36, p = 0.002). The correlations between our study and those found in the studies mentioned above suggest, that lens vault increase and its correlations are similar across geographies. In the study by Nongpuir et al.[10], the participants included Singaporeans of Chinese ethnicity. The study by Rivero[12] included participants from Spain.

Lens thickness values have been documented to be higher in patients with PACG. The significant correlation between lens vault and lens thickness needs further study, especially a higher lens vault, which may not be found in normals, with lens thickness values similar to those in PACG subjects. That is in normal subjects with increased lens thickness lens vault measurements may be less than in PACG eyes. Rivero et al.[12] found a correlation between LV and axial length. However, no such correlation was seen in the eyes from central India. We felt that studying the correlation of Lens vault with AQD was more important than ACD since the corneal thickness varies and this may affect the ACD and the correlation. It is obvious that increased lens vault influences the angle parameters of AOD and TISA and is negatively significantly associated with them.

While several parameters may be involved in the development of PACG, lens vault is also important because of the significant interest in the role of the crystalline lens in the etiopathogenesis of PACG and also in the management of PACG. It may also be an important parameter associated with other anterior segment parameters in determining the risk of developing PACG. PACG continues to be an important public health ophthalmological challenge in view of the higher possibility of vision loss over a relatively short period of time in these patients.

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