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Correlation between visual acuity and contrast sensitivity in early cataract and glaucoma. A comparative cross-sectional study

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HIGHLIGHTS

Visual acuity often remains relatively preserved in the early stages of early glaucoma and cataracts, whereas contrast sensitivity deteriorates significantly earlier. In glaucoma, early decline in contrast sensitivity is linked to subtle optic nerve damage, while in cataracts, lens opacity disrupts light scattering, affecting visual quality even before visual acuity is substantially compromised.

ABSTRACT

Background: The study investigates the correlation between visual acuity (VA) and contrast sensitivity (CS) in patients with early cataracts and glaucoma, comparing these findings with a control group. This aims to identify visual impairments associated with each condition to enhance diagnostic and therapeutic strategies.

Methods: A cross-sectional study of 213 patients using non-probability consecutive sampling included 75 with early cataracts, 75 with early glaucoma, and 63 controls, all with a best corrected visual acuity (BCVA) of ≥1.0 logMAR. Pre-dilation assessments included medical history, glaucoma status, and lens opacification; BCVA was recorded post-refraction. CS was measured with the MARS chart at 1 m. Data were analysed using SPSS version 21.

Results: Glaucomatous eyes showed mean VA of 0.72 (±0.85) (right eye) and 0.86 (±1.02) (left eye), with CS of 0 (±0) and 4 (±5) respectively. A strong negative correlation was observed between VA and CS in glaucomatous (r = -0.69; p <0.001) and cataract eyes (r = -0.71; p <0.001). Glaucomatous eyes significantly differed in VA from controls: mean 0.45 (±0.28), Z score 7.6; p <0.001, as did cataract eyes: mean 0.4 (±0.3), Z score -5.8; p <0.001. CS in glaucomatous eyes deviated significantly: mean 0.84 (±0.33), Z score -9.05; p <0.001, as did cataract eyes: mean 0.89 (±0.3), Z score -8.63; p <0.001.

Conclusion: Both glaucomatous and cataract eyes showed negative correlation between VA and CS, with significant differences compared to controls.

Key words: contrast sensitivity, glaucoma, cataracts, visual acuity

INTRODUCTION

Visual acuity (VA), linked to vision clarity, evaluates one's ability to identify minute details accurately. It depends on optical elements affecting the precision of the image on the retina and neural components, including the well-being of the retina, neural pathways to the brain, and the brain's interpretative abilities [1]. They help to identify vision problems and eye disorders, such as myopia (nearsightedness), hyperopia (farsightedness), astigmatism, age-related macular degeneration, cataracts, and glaucoma [2]. Visual acuity tests are often used in school screenings, driver's license examinations and workplace assessments to ensure that individuals have adequate vision for specific tasks and responsibilities [3]. Visual acuity can be measured by using different charts, including the Snellen acuity chart, E chart, and Landolt C chart. Visual acuity assessment through the LogMAR is a more precise and standardized way to measure visual acuity compared to traditional methods like the Snellen chart [4]. Contrast sensitivity (CS) is an individual's capacity to perceive fine details, sharp outlines, and subtle variations in shading and patterns, allowing for the identification of objects with unclear borders against their background [5]. Crucial for detecting objects lacking distinct boundaries, CS involves mechanisms like the neuronal theory, channel theory, and the M and P cellular pathways. CS is measured by using a Mars CS chart at a distance of 1 m, having log CS values ranging from 0.04 to 1.92 [6]. Assessing CS offers valuable additional insights into a patient's visual capabilities, insights that may not be apparent through VA alone. The objective of this study was to explore the extent of disparity between these two significant measures by quantifying and contrasting their connection in two prevalent eye conditions – cataracts and glaucoma. A cataract is a dense, cloudy area that forms in the lens of the eye. The impact of a cataract on both high-contrast visual acuity (spatial resolution) and CS varies depending on its density and subtype [7]. Glaucoma comprises a set of eye conditions that result in optic nerve damage, a crucial component for conveying visual information from the eye to the brain. Elevated intraocular pressure (IOP) frequently causes this damage, potentially leading to vision loss if not addressed [8]. Termed the "silent thief of sight," glaucoma is characterized by a gradual and often unnoticed decline in vision over an extended duration. Risk factors for glaucoma include ageing, a family history of the condition, and specific medical conditions or medications. Detecting these early changes in CS is crucial for the early diagnosis and management of open-angle glaucoma. In cases where VA remains relatively unaffected, especially during the initial phases of eye diseases, it is uncertain whether CS impairments are prone to develop rapidly for particular eye conditions. McKendrick et al. [9] examined low-spatial-frequency contrast sensitivity in glaucoma and ageing, involving 16 patients and age-matched controls. Older controls showed reduced sensitivity in both magnocellular and parvocellular pathways compared to the younger group. Glaucoma patients exhibited further non-selective sensitivity reduction in areas of visual field loss, indicating equivalent impairments in low-spatial-frequency-sensitive components of both pathways in early glaucoma, with additional sensitivity reduction associated with normal ageing. The study emphasizes the importance of including CS measures in clinical trials. As CS may decline at different rates across pathologies, it becomes a valuable outcome measure for assessing the effectiveness of interventions and treatments. Including contrast enhancers in clinical trials may provide a more comprehensive evaluation of visual response to therapeutic interventions. The use of yellow-tinted lenses or filters during the treatment of these diseases in their early stages is known to enhance visibility in low-light conditions and reduce sensitivity to glare, providing a more comfortable visual experience.

MATERIAL AND METHODS

A comparative cross-sectional study was conducted to investigate the correlation between VA and CS in early cataract and glaucoma from January 2023 to February 2024. The sample size was determined using Open Epi Software, Version 3.0, with a 95% confidence interval (CI), employing consecutive random sampling. The study had institutional review board approval from the IRB committee with reference number: (ERC-46/AST-23) and followed the Helsinki Declaration principle. Fully informed written consent was obtained from the study subjects. Subjects having early cataracts and glaucoma (n = 128) with no previous surgical history, aged 35–65, and best corrected visual acuity (BCVA) ≥1.0 logMAR were included. History of patients was taken in cases of glaucoma, and the opacification of the lens was checked by using a pin torch before dilation. VA of patients was noted by using logMAR. After subjective refraction, BCVA was noted. CS was measured by using a MARS contrast sensitivity chart at a distance of 1 m, having log CS values ranging from 0.04 to 1.92. Testing was performed with the eyes undilated with corrective lenses and with the occluder on the untested eye. The contrast of each numeral, reading from left to right, and continuing on successive lines and down the chart decreases by a factor (0.04 log unit). The patient read the numerals across the lines and down the chart. The contrast of the final numeral before which the patient misidentifies two consecutive numerals with a correction for earlier incorrect responses determined log contrast sensitivity. Full ophthalmological procedures were performed, including slit lamp examination, anterior segment examination, posterior segment examination, and intra-ocular pressure measurement. Patients diagnosed with early cataracts and glaucoma who met the inclusion criteria were identified and recruited. Similarly, control subjects within the specified age group but without any pathology and having BCVA ≥1.0 logMAR were recruited.

RESULTS

The study involved 213 patients: 75 with early cataracts, 75 with early glaucoma, and 63 controls. Each group included 22 patients with unilateral conditions, totalling 128 eyes per group. The control group comprised 30 males (mean age 53) and 33 females (mean age 51). In the glaucoma group, there were 43 males (57.33%) and 32 females (42.67%), while the cataract group had 40 males (51.76%) and 35 females (48.24%). Table 1 summarizes age statistics by gender in glaucoma and cataract groups: males with glaucoma averaged 53.21 (±9.14) years and females 53.95 (±8.86) years, while males with cataracts averaged 52.22 (±9.56) years and females 51.99 (±8.9) years.

TABLE 1

Descriptive statistics of age among both genders for glaucoma and cataract patients.

Condition	Gender	Age: mean (±SD)	Minimum age (years)	Maximum age (years)
Glaucoma	male	53.21 (±9.14)	32	66
	female	53.95 (±8.86)	36	66
Cataract	male	51.99 (±8.90)	33	67
	female	51.77 (±8.59)	36	65

SD – standard deviation.

Table 2 displays VA and CS statistics for glaucoma and cataract eyes. Glaucoma eyes had mean VA 0.72 (±0.85), range: 1.05–1.08, and CS for right eye 0 (±0) and for left eye 4 (±5). Cataract eyes had mean VA 1.02 (±1.48), range: 0–5, and CS 1.04 (±0.53), range: 0.16–2.44, illustrating their variability.

TABLE 2

Descriptive statistics of visual acuity and contrast sensitivity in glaucomatous and cataract eyes.

Condition	Measurement	Mean (±SD)	Minimum	Maximum
Glaucoma	VA CC OD	0.72 (±0.85)	0.16	1.08
	VA CC OS	0.86 (±1.02)	0.61	0.67
	GE CS OD	0 (±0)	0.16	0.16
	GE CS OS	4 (±5)	2.44	2.44
Cataract	VA CC OD	1.02 (±1.48)	0	5
	VA CC OS	0.67 (±0.85)	0	4
	CE CS OD	1.2 (±0.66)	0.24	2.44
	CE CS OS	1.04 (±0.53)	0.16	2.44

CE CS OD – contrast sensitivity of right eyes with cataract; GE CS OS – contrast sensitivity of left eyes with cataract; GE CS OD – contrast sensitivity of right eyes with glaucoma; GE CS OS – contrast sensitivity of left eyes with glaucoma; VA CC OD – best corrected visual acuity of right normal eyes; VA CC OS – best corrected visual acuity of left normal eyes.

Table 3 shows a strong negative correlation between VA and CS in glaucomatous eyes (r = -0.69; p <0.001) and cataract eyes (r = -0.71; p <0.001), rejecting the null hypothesis.

TABLE 3

Correlation analysis of visual acuity with contrast sensitivity in glaucomatous and cataract eyes.

Condition	Variables	N	r-value	p-value
Glaucoma	VA GE and CS GE	128	-0.69	<0.001*
Cataract	VA CE and CS CE	128	-0.71	<0.001*

CS CE – contrast sensitivity of cataract eyes; CS GE – contrast sensitivity of glaucomatous eyes; VA CE – visual acuity of cataract eyes; VA GE – visual acuity of glaucomatous eyes; r-value – Spearman correlation analysis.

VA was compared between glaucomatous and cataract eyes and their respective controls using non-normal data distribution tests. Glaucomatous eyes – mean VA = 0.45 (±0.28) – and cataract eyes – mean VA = 0.4 (±0.3) – showed significantly higher VA than controls – mean VA = 0.2 (±0.23); p <0.001 for both comparisons, as indicated in table 4 and figure 1 (for glaucoma) and figure 2 (for cataracts). These findings emphasize the impact of these conditions on VA.

TABLE 4

Comparison of visual acuity of pathology specific eyes with their controls.

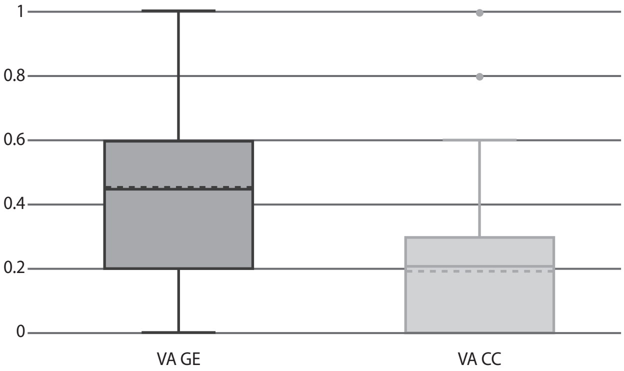
Comparison	Measurement	N	Mean (±SD)	Median	Mean rank	Z score	Exact significance (p-value)
Glaucoma and controls	VA GE	128	0.45 (±0.28)	0.45	163.08	-7.6	<0.001*
	VA CC	128	0.2 (±0.23)	0.2	93.92		
Cataract and controls	VA CE	128	0.4 (±0.3)	0.3	155.01	-5.8	<0.001*
	VA CC	128	0.2 (±0.23)	0.2	101.99		

VA CC – best corrected visual acuity of normal eyes; VA CE – visual acuity of cataract eyes; VA GE – visual acuity of glaucomatous eyes; z score – *Mann-Whitney U test.

CS was compared between glaucomatous and cataract eyes and their respective controls using statistical tests. Glaucomatous eyes (CS GE, N = 128) showed a mean CS of 0.84 (±0.33), significantly lower than controls (CS NE, N = 128) with a mean of 1.22 (±0.29; p <0.001), as illustrated in figure 3 and table 5. Similarly, cataract eyes (CS CE, N = 128) exhibited a mean CS of 0.89 (±0.3), also significantly lower than controls (CS NE) with a mean of 1.22 (±0.29; p <0.001), shown in figure 4. These findings reject the null hypothesis and underscore distinct CS characteristics associated with both glaucoma and cataracts.

FIGURE 1

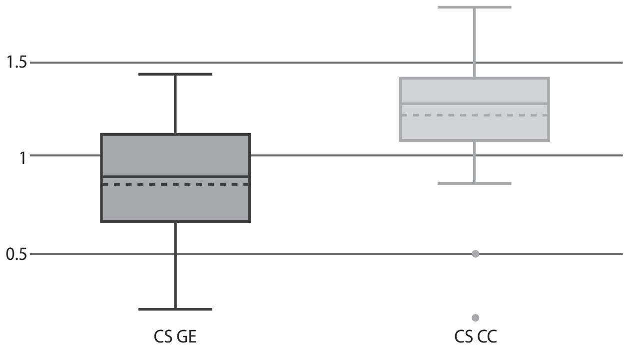
Comparison of visual acuity of glaucomatous eyes with their controls.



VA CC – best corrected visual acuity of normal eyes; VA GE – visual acuity of glaucomatous eyes.

FIGURE 3

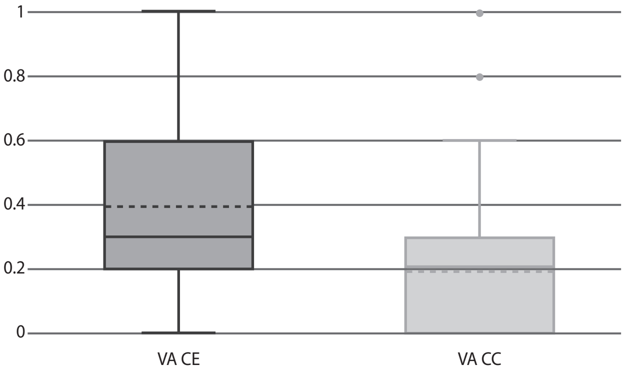
Comparison of contrast sensitivity of glaucomatous eyes with their controls.



CS GE – contrast sensitivity of glaucomatous eyes; CS NE – contrast sensitivity of normal eyes.

FIGURE 2

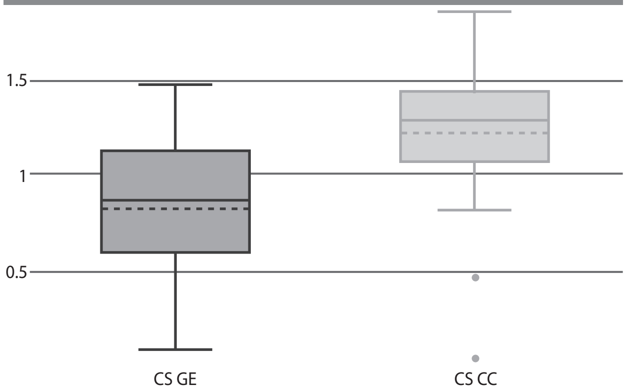
Comparison of visual acuity of cataract eyes with their controls.



VA CC – best corrected visual acuity of normal eyes; VA CE – visual acuity of cataract eyes.

FIGURE 4

Comparison of contrast sensitivity of cataract eyes with those of their controls.



CS CE – contrast sensitivity of cataract eyes; CS NE – contrast sensitivity of normal eye.

DISCUSSION

VA is a fundamental measure in eye clinics and clinical trials, [7] while CS captures aspects of visual function not assessed by VA. CS is underutilized in routine exams and trials. This study quantified and compared VA and CS relationships across early cataracts, glaucoma, and healthy subjects, aiming to assess their dissociation.

Previous literature reviews of clinical trials for age-related macular degeneration treatments found that, although VA was often reported as the primary outcome, some treatments (e.g., verteporfin therapy) may provide additional benefits to CS. Butt et al. reported that CS was a more sensitive outcome measure than VA for demonstrating the cost-effectiveness of an anti-vascular endothelial growth factor (anti-VEGF) treatment [8].

TABLE 5

Comparison of contrast sensitivity of pathology specific eyes with their controls.

Comparison	Measurement	N	Mean (±SD)	Median	Mean rank	Z score	Exact significance (p-value)
Glaucomatous eyes and controls	CS GE	128	0.84 (±0.33)	0.88	86.76	-9.05	<0.001*
	CS NE	128	1.22 (±0.29)	1.28	170.24		
Cataract Eyes and controls	CS CE	128	0.89 (±0.3)	0.92	88.74	-8.63	<0.001*
	CS NE	128	1.22 (±0.29)	1.28	168.26		

CS CE – contrast sensitivity of eyes with cataract; CS GE – contrast sensitivity of glaucomatous eyes; CS NE – contrast sensitivity of normal eyes; z score – *Mann-Whitney U test.

Including CS in screening tests is essential because individuals with apparently normal VA can still have CS deficits [9]. This addition improves the detection of certain eye conditions affecting visual function. Given that CS can be impaired even with maintained VA, it is crucial to refer patients reporting functional difficulties to vision rehabilitation services. These services offer various visual aids like bold print, task lighting, optical magnifiers, and video magnifiers, which enhance contrast and provide benefits regardless of VA level [10].

When VA is less than 0.6 logMAR, early CS deficits are likely associated with different aspects of the underlying retinal pathology. Even in the initial phases of glaucoma, notable macular damage involving the loss of retinal ganglion cells and the reduction in dendritic structures and cell bodies of remaining cells has been identified [11]. This observation could provide a plausible explanation for the observed contrast sensitivity deficits in glaucoma cases, even when visual acuity appears relatively normal.

Cataracts, even in their early development, can impact the eye's ability to perceive these subtle differences in contrast, leading to contrast sensitivity deficits. Two key findings emerged from this study:

1. When VA is relatively normal, the extent of CS deficits is quantitatively different across ocular pathologies.
2. The overall quantitative relationship between CS deficit and VA deficit varies across pathologies.

In the glaucoma group, 57.33% of patients were males (43), while 42.67% were females (32). For the cataract group, 51.76% were males (40) and 48.24% were females (35). This data highlights the gender distribution within both ocular conditions. In the control group, the gender distribution is balanced with 33 males (52.38%) and 30 females (47.62%). The mean age (±SD) for males is 47.62 (±8.37) years, ranging from 34 to 65 years, while for females, it is 48.7 (±9.01) years, with the same age range.

Richman et al. reported that performance on the Assessment of Disability Related to Vision (ADREV) was most strongly associated with binocular visual acuity ($r = -0.79$; $P < 0.001$) and binocular contrast sensitivity ($r = 0.80$; $P < 0.001$). Monocular and binocular visual field test results correlated with the ability to perform ADREV tasks but had a significantly weaker association ($P < 0.05$) compared to visual acuity and contrast sensitivity [12]. Our study showed a significant negative association between visual acuity in glaucomatous eyes (VA GE) and contrast sensitivity in glaucomatous eyes (CS GE), with a Spearman's rho of -0.69 and a p-value of <0.001 in a sample of 128, indicating a strong negative correlation.

Similarly, a correlation analysis was performed to explore the potential negative association between visual acuity in cataract eyes (VA CE) and contrast sensitivity in cataract eyes (CS CE). The findings revealed a highly significant negative association, as indicated by a Spearman's rho (r) value of -0.71 and a p-value of <0.001, based on a sample size of 128. This points to a very high, negative correlation between the variables VA CE and CS CE, with an r-value of -0.71.

The same study was conducted by Maraini et al., in which the analysis utilized data from 1,076 eyes, including 366 clear lenses and various cataract types (550 cortical, 124 nuclear, and 36 posterior subcapsular cataracts). In age-adjusted analyses, increasing cataract severity correlated with worsened VA and lower CS scores. Notably, this impact was most significant in nuclear cataracts and least in cortical opacities. However, after additional adjustments for age and VA, the associations between CS scores and cataract type and severity diminished, except for advanced cortical opacities [13].

The study compares visual acuity between glaucomatous eyes and their controls, as well as eyes with cataracts and their controls. In the case of glaucomatous eyes (VA glaucomatous eyes), the sample size was 128, with a mean visual acuity of 0.45 (±0.28) and a median of 0.45. The statistical analysis, including the mean rank and Z score, indicated a highly significant difference compared to controls (VA normal eye). The null hypothesis, suggesting that glaucomatous eyes have smaller or equal values than controls, was rejected with a p-value of <0.001.

Similarly, for eyes with cataracts (VA CE) and their controls (VA CC), the comparison revealed a mean visual acuity of 0.4 (±0.3) and a median of 0.3 in the cataract group. This was significantly different from the controls, with a mean rank of 155.01 and a Z score of -5.8, yielding a highly significant p-value of <0.001. The descriptive statistics indicated that the cataract eye group had higher values for the dependent variable than the controls. The rejection of the null hypothesis through a one-tailed Mann-Whitney U-Test emphasized the substantial impact of cataracts on VA.

A comprehensive analysis of contrast sensitivity revealed a significant difference between glaucomatous eyes (CS GE) and controls (CS NE). In 128 glaucomatous eyes, the mean contrast sensitivity was 0.84 (±0.33) with a median of 0.88, significantly lower than the control group's mean of 1.22 (±0.29) and median of 1.28 ($p < 0.001$). Sample et al. found a significant decline in contrast sensitivity in glaucomatous eyes, especially at 12 cycles per degree ($P < 0.012$), while eyes with ocular hypertension showed no significant differences from normal eyes [14].

In eyes with cataracts (CS CE), a sample of 128 showed a mean contrast sensitivity of 0.89 (±0.3) and a median of 0.92, significantly lower than controls (CS NE) with a mean of 1.22 (±0.29) and a median of 1.28 ($p < 0.001$). A one-tailed Mann-Whitney U-Test confirmed these differences, rejecting the null hypothesis. The study highlights significant

negative correlations between VA and contrast sensitivity in eyes with glaucoma and cataracts, suggesting age and VA as influential covariates [15, 16]. A significant negative correlation was identified between VA and CS in eyes afflicted by glaucoma and those with cataracts. When VA and CS were compared between glaucomatous eyes and their corresponding controls, as well as between cataract eyes and their controls, notable differences were observed.
This study's limitations include the non-probability consecutive sampling method, which restricts the generalizability of the results. Additionally, the cross-sectional design does not allow for causal inferences between visual acuity, contrast sensitivity, and the conditions studied. Furthermore, the lack of control for potential confounding factors, such as other ocular or systemic conditions, could have influenced the findings.

CONCLUSION

Both glaucomatous and cataract eyes showed negative correlation between VA and CS, with significant differences compared to controls. In both cataract and glaucoma, CS tends to decline before VA is affected. This makes CS a more sensitive measure of early changes in the visual system, especially in conditions like cataract (grade 1, 2) and glaucoma (early stage). Therefore, CS testing could be an important tool for early detection and monitoring of functional vision loss in these patients.

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Rabia Faheem – conception and design, data acquisition, analysis and interpretation, drafting.
Muhammad Saad – revising and critical review, analysis and interpretation.
Saif Ullah – revising and critical review, final approval of work, and accountable for all aspects of the work.
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