



ASSESSING THE IMPACT OF ANEMIA ON CENTRAL CORNEAL THICKNESS AND INTRAOCULAR PRESSURE

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ABSTRACT:

Background: Anemia is a systemic disorder that can influence ocular physiology through reduced oxygen delivery. This study evaluated the impact of anemia on central corneal thickness (CCT) and intraocular pressure (IOP) and examined the relationship between anemia severity and ocular parameters.

Methods: In this cross-sectional study, 90 patients with anemia and 90 age-matched healthy controls underwent comprehensive ocular evaluation, including specular microscopy for CCT and non-contact tonometry for IOP. Hematological profiles—including hemoglobin, ferritin, red blood cell indices, and red cell distribution width (RDW)—were assessed. Correlation analyses examined associations between anemia severity and ocular changes.

Results: Anemic patients exhibited significantly thinner CCT (RE: $519.88 \pm 4.27 \mu\text{m}$ vs. $541.63 \pm 6.90 \mu\text{m}$; LE: $519.77 \pm 4.35 \mu\text{m}$ vs. $541.98 \pm 6.81 \mu\text{m}$; $p < 0.01$) and lower IOP (RE: $13.73 \pm 1.03 \text{ mmHg}$ vs. $16.41 \pm 1.68 \text{ mmHg}$; LE: $14.10 \pm 1.19 \text{ mmHg}$ vs. $16.78 \pm 2.09 \text{ mmHg}$; $p < 0.01$) compared to controls. Both CCT and IOP positively correlated with hemoglobin levels, with greater reductions in moderate-to-severe anemia. Elevated RDW and platelet indices reflected systemic hematological disturbances.

Conclusion: Anemia is associated with significant anterior segment changes, including reduced CCT and lower IOP, with severity of anemia directly influencing these parameters. These findings highlight the importance of considering hematological status in ophthalmic evaluations to ensure accurate IOP assessment and early detection of potential ocular complications.

Keywords: Anemia, central corneal thickness, intraocular pressure, hematological indices, ocular hypoxia, RDW

INTRODUCTION:

Corneal transparency is critically dependent on the metabolic activity of corneal endothelial cells, which require a continuous and adequate supply of oxygen to maintain stromal dehydration and optical clarity.¹ Any systemic condition that compromises oxygen delivery has the potential to adversely affect corneal structure and function.

Anemia is a major global public health problem, affecting approximately one-third of the world's population.² It is clinically defined as a reduction in blood hemoglobin (Hb) concentration or hematocrit below the lower limit of the reference range for age and sex, with Hb levels <12 g/dL in females and <13 g/dL in males commonly used as diagnostic thresholds.³ Hemoglobin plays a vital role in transporting oxygen from the lungs to peripheral tissues, and reduced Hb levels can lead to systemic hypoxia.⁴

Chronic hypoxia resulting from anemia may induce ischemic and metabolic alterations in various tissues, including ocular structures. The cornea and crystalline lens are particularly vulnerable because they are avascular and depend on diffusion of oxygen and nutrients from the aqueous and vitreous humor. Impaired oxygen delivery may therefore influence corneal endothelial function, potentially affecting central corneal thickness (CCT) and intraocular pressure (IOP), both of which are clinically significant parameters in glaucoma assessment and management.

Previous studies have demonstrated reduced central corneal thickness and choroidal thickness in pediatric patients with sickle cell anemia and iron deficiency anemia.^{5,6} These findings suggest that anemia may influence ocular structural parameters. However, despite these observations, the relationship between anemia and key ophthalmic measurements such as CCT and IOP remains inadequately investigated, particularly in adult populations and in the context of glaucoma risk assessment.

OBJECTIVES :

1. To assess the impact of anemia on central corneal thickness (CCT)
2. To assess the impact of anemia on Intraocular Pressure (IOP)
3. To assess the correlation between anemia severity and changes in CCT and IOP.

MATERIALS AND METHODS.

This cross-sectional observational hospital-based study was conducted on a total of 90 participants, divided into two groups: Group 1, comprised patients with varying degrees of anemia, and Group 2, the control group consisted of age-matched healthy individuals. The study was carried out in the Department of Ophthalmology at R.L.J. Hospital and Research Centre, Kolar, affiliated with Sri Devaraj Urs Medical College. After obtaining approval from the Institutional Ethics Committee, information was collected from patients attending the outpatient department (OPD) through a combination of clinical examinations, patient interviews, and reviews of relevant medical history.

INCLUSION CRITERIA:

1. Participants from the age group of 45 to 75 years of either sex.
2. Participants diagnosed with varying degrees of anemia.

EXCLUSION CRITERIA:

1. Individuals with diabetes or hypertension.
2. History of using antiandrogen, antidepressant, or antihistaminic medications.
3. Previous ocular surgery or trauma.
4. Current ocular inflammation or infection.
5. Use of contact lenses.
6. Presence of pterygium.
7. History of chemical burns.
8. History of glaucoma

METHODOLOGY:

After taking written & informed consent, all the patients admitted in Ophthalmology department at RL Jalappa Hospital & Research Centre, attached to Sri Devaraj Urs Medical College who meet inclusion criteria are recruited for the study.

All participants underwent a comprehensive and standardized ophthalmic evaluation performed under uniform testing conditions to minimize inter-observer and intra-observer variability. The assessment protocol was carried out in a predefined sequence to ensure consistency across subjects.

Central corneal thickness (CCT) was assessed using specular microscopy, a non-invasive imaging technique that provides accurate measurements of the corneal endothelium and stromal thickness. Multiple readings were obtained for each eye, and the mean value was recorded to ensure precision and reproducibility of the measurements. This method also allows simultaneous evaluation of endothelial cell morphology, providing additional insights into corneal health.

Intraocular pressure (IOP) was measured using a non-contact tonometer under standardized ambient conditions. To improve reliability, multiple measurements were recorded for each participant, and the average value was considered for statistical analysis.

A comprehensive ocular examination was subsequently conducted, including detailed anterior segment evaluation and fundus examination, to identify any pre-existing ocular pathology. Particular attention was paid to detecting conditions such as ocular inflammation, infection, or corneal abnormalities that could potentially influence corneal thickness or intraocular pressure measurements. Participants with such confounding ocular conditions were excluded or appropriately documented according to the study protocol.

The data collected were systematically recorded and analyzed to assess the impact of anemia on central corneal thickness and intraocular pressure, and to compare these parameters between anemic patients and healthy controls.

STATISTICAL ANALYSIS:

Data were entered into a Microsoft Excel spreadsheet and subsequently analyzed using Statistical Package for the Social Sciences (SPSS) software, version 22. Categorical variables were summarized as frequencies and proportions, and the Chi-square test was applied to assess associations between categorical variables.

Continuous variables were expressed as mean $\pm$ standard deviation (SD). Analysis of variance (ANOVA) was used to compare mean differences among the study groups where applicable.

Graphical representation of data: MS Excel and MS word was used to obtain various types of graphs

P value of <0.05 was considered as statistically significant after assuming all the rules of statistical tests.

RESULTS:

Demographic Distribution and Baseline Characteristics: The study consisted of 180 participants evenly divided into 90 anemic cases and 90 healthy controls. The sex distribution revealed a pronounced female predominance in the anemic group, with 65 females accounting for 72.2% of cases, compared to 25 males (27.8%). Conversely, the control group showed a more balanced sex ratio (51.1% female, 48.9% male). This skew toward female predominance in anemia is consistent with epidemiological data attributing higher anemia risk in females to menstrual blood loss, reproductive factors, and possibly nutritional deficiencies (see Table 1).

Sex	Cases (N=90)	Percentage (%)	Controls (N=90)	Percentage (%)
Female	65	72.2	46	51.1
Male	25	27.8	44	48.9

Table 1: Sex distribution among cases and controls.

Age was comparable across groups with mean ages of 62.32 ± 5.61 years in cases and 61.17 ± 6.84 years in controls ($p = 0.217$). This similarity reduces age as a confounding factor in ocular and hematological measurements, ensuring that differences observed are attributable primarily to anemia status.

Central Corneal Thickness (CCT) Differences

The study demonstrated a statistically significant reduction in central corneal thickness (CCT) among patients with anemia compared to age-matched healthy controls. In the right eye, anemic subjects exhibited a mean CCT of $519.88 \pm 4.27 \mu\text{m}$, whereas the control group had a mean CCT of $541.63 \pm 6.90 \mu\text{m}$ ($p < 0.01$). Similarly, the left eye CCT was $519.77 \pm 4.35 \mu\text{m}$ in cases and $541.98 \pm 6.81 \mu\text{m}$ in controls ($p < 0.01$), indicating consistent thinning across both eyes (Table 2).

Parameter	Group	Mean CCT (μm)	SD	P value
Right Eye CCT	Cases	519.88	4.27	<0.01
	Control	541.63	6.90	
Left Eye CCT	Cases	519.77	4.35	<0.01
	Control	541.98	6.81	

Table 2: Comparison of central corneal thickness (CCT) between anemic patients and healthy controls.

This reduction in CCT among anemic patients was both statistically significant and clinically relevant. Thinner corneas in the anemic population likely reflect **systemic hypoxia-induced alterations in corneal physiology**. Chronic anemia reduces hemoglobin-mediated oxygen delivery, potentially compromising the metabolic activity of corneal endothelial cells. Impaired endothelial pump function can lead to altered stromal hydration and structural thinning of the cornea.

Clinically, thinner corneas have important implications for ophthalmic evaluation. CCT directly influences intraocular pressure (IOP) measurements obtained via applanation tonometry. In patients with anemia, underestimation of true IOP is a concern, which could mask ocular hypertension or delay glaucoma diagnosis. Moreover, the severity of anemia was positively correlated with the degree of corneal thinning, suggesting a **dose-response relationship**, wherein patients with moderate-to-severe anemia exhibited more pronounced reductions in CCT compared to those with mild anemia.

Intraocular Pressure (IOP) Differences

In this study, anemic patients demonstrated a statistically significant reduction in intraocular pressure (IOP) in both eyes compared to age-matched healthy controls. The mean IOP in the right eye of anemic subjects was $13.73 \pm 1.03 \text{ mmHg}$, markedly lower than the $16.41 \pm 1.68 \text{ mmHg}$ observed in the control group ($p < 0.01$). Similarly, the left eye IOP in cases was $14.10 \pm 1.19 \text{ mmHg}$, significantly lower than $16.78 \pm 2.09 \text{ mmHg}$ in controls ($p < 0.01$) (Table 3).

Parameter	Group	Mean IOP (mmHg)	SD	P value
Right Eye IOP	Cases	13.73	1.03	<0.01
	Control	16.41	1.68	
Left Eye IOP	Cases	14.10	1.19	<0.01
	Control	16.78	2.09	

Table 3: Comparison of mean intraocular pressure (IOP) between anemic patients and healthy controls.

The observed reduction in IOP among anemic patients is likely attributable to the systemic hypoxic state associated with chronic anemia. Reduced hemoglobin levels impair oxygen delivery to ocular tissues, including the metabolically active ciliary body, which is responsible for aqueous humor production. Hypoxia in the ciliary epithelium may reduce aqueous secretion, thereby lowering IOP. Furthermore, hypoxic conditions can influence trabecular meshwork function, potentially increasing aqueous humor outflow and contributing further to reduced intraocular pressure. Systemic anemia

may also impair ocular blood flow autoregulation, altering the balance between aqueous production and drainage and thereby modulating IOP.

These findings carry important clinical implications. Lower IOP in anemic individuals may lead to underestimation of true ocular pressure when measured using conventional tonometry, potentially masking underlying ocular hypertension and delaying the diagnosis of glaucoma. Consequently, ophthalmologists should interpret IOP measurements with caution in patients with anemia and consider integrating adjunctive diagnostic evaluations, including central corneal thickness assessment and detailed optic nerve evaluation, to accurately assess glaucoma risk and ensure appropriate clinical management.

Hematological Profile Differences

The hematological evaluation revealed pronounced differences between anemic patients and healthy controls, consistent with the profile of iron deficiency anemia (Table 4). Hemoglobin levels in anemic cases were significantly reduced, with a mean of 9.68 ± 1.52 g/dL compared to 13.11 ± 1.01 g/dL in controls ($p < 0.01$). Similarly, the red blood cell (RBC) count was lower in cases ($3.96 \pm 0.52 \times 10^6/\mu\text{L}$) than in controls ($4.54 \pm 0.47 \times 10^6/\mu\text{L}$, $p < 0.01$), confirming the impaired oxygen-carrying capacity inherent to anemia. This systemic hypoxia has potential downstream effects on ocular physiology, particularly on metabolically active tissues such as the corneal endothelium and the ciliary body, which may contribute to the reduced intraocular pressure (IOP) and thinner central corneal thickness (CCT) observed in this cohort.

Parameter	Group	Mean	SD	P value
Hemoglobin (g/dL)	Cases	9.68	1.52	<0.01
	Control	13.11	1.01	
RBC ($\times 10^6/\mu\text{L}$)	Cases	3.96	0.52	<0.01
	Control	4.54	0.47	
MCV (fL)	Cases	76.94	9.65	<0.01
	Control	84.36	5.87	
MCHC (g/dL)	Cases	31.89	2.75	<0.01
	Control	33.94	1.29	
MCH (pg)	Cases	24.94	4.29	<0.01
	Control	28.75	2.39	
Ferritin (ng/mL)	Cases	9.34	2.01	<0.01
	Control	98.38	19.25	
Platelet ($\times 10^3/\mu\text{L}$)	Cases	292.02	74.66	<0.01
	Control	266.36	64.18	
RDW (%)	Cases	16.43	7.32	<0.01
	Control	13.40	1.52	

Table 4: Comparison of hematological parameters between anemic patients and healthy controls.

Analysis of red blood cell indices revealed a microcytic, hypochromic pattern in anemic patients. Mean corpuscular volume (MCV) was significantly lower in cases (76.94 ± 9.65 fL) than in controls (84.36 ± 5.87 fL, $p < 0.01$), and mean corpuscular hemoglobin (MCH) was similarly reduced (24.94 ± 4.29 pg vs. 28.75 ± 2.39 pg, $p < 0.01$). Mean corpuscular hemoglobin concentration (MCHC) was also lower in anemic subjects (31.89 ± 2.75 g/dL vs. 33.94 ± 1.29 g/dL, $p < 0.01$), further confirming iron-deficient erythropoiesis. Ferritin levels, reflecting iron stores, were markedly depleted in cases (9.34 ± 2.01 ng/mL) compared to controls (98.38 ± 19.25 ng/mL, $p < 0.01$), indicating severe iron deficiency.

Platelet counts were elevated in anemic patients ($292.02 \pm 74.66 \times 10^3/\mu\text{L}$) relative to controls ($266.36 \pm 64.18 \times 10^3/\mu\text{L}$, $p < 0.01$), which may represent a reactive thrombocytosis secondary to iron deficiency. Red cell distribution width (RDW) was significantly higher in cases ($16.43 \pm 7.32\%$) versus controls ($13.40 \pm 1.52\%$, $p < 0.01$), reflecting substantial anisocytosis and heterogeneous erythrocyte populations typical of iron-deficient marrow activity.

The hematological profile in this study underscores the systemic nature of iron deficiency anemia and its potential to impact ocular physiology. Reduced hemoglobin levels compromise oxygen delivery to metabolically active ocular tissues, including the corneal endothelium and ciliary epithelium, contributing to the observed reductions in CCT and IOP. Elevated platelet counts and increased RDW suggest ongoing marrow compensation and systemic vascular stress, which may exacerbate microvascular alterations in ocular tissues.

Clinically, these findings highlight the importance of integrating hematological assessment with ophthalmological evaluation. In patients with anemia, tonometry-based IOP measurements may underestimate true ocular pressure, potentially delaying the detection of glaucoma. Moreover, the correlation between hematological parameters and ocular measurements suggests that systemic anemia not only affects general health but also exerts measurable effects on corneal structure and intraocular pressure regulation. Understanding these systemic-ocular interactions is essential for risk stratification and optimal management of anemic patients in ophthalmic practice.

DISCUSSION:

In this study, patients with anemia demonstrated significantly reduced central corneal thickness (CCT) and intraocular pressure (IOP) compared to age-matched healthy controls. These ocular alterations occurred alongside hematological derangements characteristic of anemia, suggesting that systemic hypoxia and impaired oxygen delivery exert measurable effects on anterior segment parameters and ocular physiology. Importantly, the magnitude of CCT reduction and IOP lowering correlated with the severity of anemia, with patients exhibiting lower hemoglobin and ferritin levels showing greater corneal thinning and lower intraocular pressure, indicating a dose-dependent relationship between hematological impairment and ocular changes.

The observed reduction in CCT, measured using specular microscopy, aligns with prior clinical studies. Women with iron and vitamin B12 deficiency anemia were found to have significantly thinner CCT compared with healthy controls, implying that systemic hematologic abnormalities may compromise corneal endothelial integrity and stromal hydration⁷. Hypoxia-induced endothelial dysfunction and impaired corneal metabolism likely contribute to corneal thinning, which is more pronounced in patients with severe anemia. Specular microscopy allows direct assessment of endothelial cells, emphasizing the functional and structural basis of these corneal changes.

The significant decrease in IOP among anemic patients supports the hypothesis that systemic hypoxia can modulate aqueous humor dynamics. Corneal thickness and biomechanics influence tonometric measurements, and thinner corneas, as seen in anemia, may lead to underestimation of true IOP, potentially masking ocular hypertension and delaying glaucoma diagnosis⁸. Furthermore, chronic anemia may reduce oxygen delivery to the ciliary epithelium, impair aqueous humor production, or alter trabecular meshwork function, further lowering IOP. The severity of anemia amplifies these effects, as patients with more profound hemoglobin deficits showed lower IOP.

Beyond anterior segment changes, systemic anemia is associated with posterior segment structural alterations. Retinal nerve fiber layer (RNFL) thickness is significantly reduced in anemic adults, with reductions across multiple quadrants and positive correlations with hemoglobin, iron, and ferritin levels. Pediatric studies similarly report thinner RNFL in anemic children, correlating with hemoglobin levels⁹. Choroidal thickness is also affected, with reduced measurements at the fovea and across nasal and temporal quadrants in children with anemia, correlating with systemic hematologic parameters⁵.

The pathophysiological link between anemia and ocular changes can be explained by iron's critical role in oxygen transport and cellular metabolism. Reduced hemoglobin-mediated oxygen delivery induces tissue hypoxia, impairing corneal endothelial pump function, stromal hydration, and retinal

and choroidal perfusion¹. A recent systematic review and meta-analysis confirmed that individuals with iron deficiency anemia have significantly thinner RNFL, reduced foveal avascular zone, and lower retinal capillary plexus densities compared to healthy controls¹⁰. These findings underscore the graded impact of anemia severity on ocular structures.

Clinically, these results have important implications. Since CCT influences IOP measurement and glaucoma risk assessment, thinner corneas and lower IOP in anemic patients may result in underestimation of true intraocular pressure, particularly in individuals with more severe anemia⁸. Posterior segment changes, such as RNFL and choroidal thinning, may serve as early indicators of systemic hypoxic stress, supporting the use of ocular imaging for comprehensive monitoring in patients with chronic anemia. Overall, these findings highlight the importance of integrating hematological evaluation into ophthalmic assessment to prevent misinterpretation of IOP and allow early detection of ocular complications in anemic populations

CONCLUSION:

This study demonstrates that anemia, is associated with significant reductions in central corneal thickness and intraocular pressure compared to age-matched healthy individuals. The severity of anemia correlates with the magnitude of these ocular changes, with more profound hematological deficits resulting in thinner corneas and lower IOP. These findings underscore the systemic impact of anemia on ocular physiology, highlighting the risk of underestimating true intraocular pressure in anemic patients and the potential for delayed glaucoma diagnosis. Clinicians should consider hematological status when interpreting corneal and IOP measurements, and integrated ophthalmic and hematologic evaluation is recommended for optimal assessment and management in populations with high anemia prevalence.

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