Section: Miscellaneous

Original Research Article

EVALUATION OF MARKERS OF INFLAMMATION AND TOTAL ANTIOXIDANT CAPACITY IN DIABETIC RETINOPATHY

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ABSTRACT

Background: Serum ferritin, ceruloplasmin, neutrophil-lymphocyte ratio (NLR) and total antioxidant capacity (TAC) have an association in the pathogenesis of type 2 diabetes mellitus and its progression to diabetic retinopathy (DR). **Aim:** To evaluate the markers of inflammation (Serum ferritin, ceruloplasmin and NLR) and total antioxidant capacity in diabetic retinopathy.

Settings and Design: A cross-sectional observational study was conducted on 96 patients comprising of three groups, 32 T2DM patients complicated with diabetic retinopathy, 32 T2DM patients without diabetic retinopathy and 32 healthy controls based on American Diabetes Association 2019 HbA1c% level criteria and ophthalmic examination.

Methods and Materials: Estimation of serum insulin, ferritin, ceruloplasmin and NLR was done on chemiluminescence based, immunoturbidimetric and haematology analysers respectively. Serum TAC was assayed using ELISA technology. Data was analysed using SPSS version 26.0.

Results: Mann Whitney U analysis showed that levels of HbA1c%, HOMA-IR, ferritin, ceruloplasmin, NLR and TAC were significantly different among the three study groups. Spearman test showed a significant positive correlation between these parameters and an inverse correlation with TAC. The ROC curve, shows TAC as the best predictor of diabetic retinopathy with AUC of 0.936 followed by ceruloplasmin (0.844), ferritin (0.760) and NLR (0.646).

Conclusion: Elevated levels of ceruloplasmin and ferritin coupled with decreased TAC levels are good indicators for diabetic retinopathy and may be used as a diagnostic tool to predict the occurrence of retinopathy.

Keywords: Ferritin, ceruloplasmin, NLR, Total antioxidant capacity, Diabetic retinopathy.

INTRODUCTION

Diabetic retinopathy (DR) is a significant global health problem, leading to vision loss and blindness among adults and the elderly across the world.[1] The combination of multiple factors, including an inflammatory response and oxidative imbalance, contribute to microvascular irregularities in the retina, such as neovascularization, macular edema, and retinal detachment. These vascular changes are indicative of progression of diabetic retinopathy (DR) and serve as key markers of retinal injury.[2,3,4,5] In diabetes, elevated blood glucose levels stimulate excessive production of reactive oxygen species (ROS) via mechanisms such as glucose auto-oxidation, dysfunction of the polyol pathway, non-enzymatic protein glycation, and oxidative breakdown of glycated proteins. The accumulation of free radicals, coupled with weakened antioxidant

defences, can harm cellular structures and contribute to the onset of insulin resistance.[6]

Ferritin, an iron storage protein, plays a key role in the development of diabetic retinopathy by promoting iron-induced oxidative stress, inflammation and endothelial dysfunction. Increased ferritin levels may reflect iron overload, which enhances the generation of reactive oxygen species (ROS) and contributes to diabetic complications. [7]

Ceruloplasmin, a copper-binding glycoprotein, functions as a late-phase acute protein and serves as a prominent marker of low-grade chronic inflammation.[8] Ceruloplasmin facilitates the incorporation of iron into transferrin while preventing the formation of harmful iron byproducts. During this redox reaction, oxygen is reduced directly to water, which may also explain ceruloplasmin's ability to inhibit superoxide-induced lipid peroxidation.[9]

The neutrophil-to-lymphocyte ratio (NLR) represents the balance between pro-inflammatory neutrophils and anti-inflammatory lymphocytes. Multiple studies have shown a positive correlation between high NLR levels and severity of diabetic retinopathy (DR), indicating that NLR may serve as a useful biomarker for identifying individuals at risk of DR and tracking its progression.[10]

The total antioxidant status (TAS) reflects the combined effect of both endogenous and dietary antioxidants within the system. Assessing TAS is considered more meaningful than evaluating individual antioxidant levels, as antioxidants function synergistically to provide overall protection against oxidative stress.[11] Studies have demonstrated that total antioxidant status (TAS) is markedly reduced in diabetic patients with proliferative retinopathy compared to those without retinopathy. [12,13]

Therefore, early detection of DR and its management is important to prevent disabling visual loss from DR. The present study focuses on the early identification of the disease process, thereby minimizing retinal function loss and heralding an improvement in the management of diabetic retinopathy.

MATERIALS AND METHODS

The study was conducted after taking ethical clearance from the institutional ethics committee of a tertiary care hospital in the national capital (ABVIMS & Dr. RML Hospital)

Study design: Cross sectional observational study

Study group: Three groups comprising of 96 consenting adults, 32 patients with T2DM complicated with diabetic retinopathy, 32 patients of T2DM without diabetic retinopathy and 32 healthy controls age and sex matched from patients visiting OPD in the department of Medicine and Ophthalmology and healthy controls from the general population.

Study Period: 1st April 2023 to 30th June 2024.

Calculation of sample size: The required sample size with 80% power of and 5% level of significance was calculated as 32 patients in each of the study groups. In this study 96 consenting adults (32 with Type 2 Diabetes Mellitus without complications, 32 with diabetic retinopathy, and 32 age- and sex-matched healthy controls), with no other diagnosed systemic diseases or history of laser treatment and ocular surgery for at least 12 months were included.

Candidates on anti-inflammatory drugs, antioxidants, or omega-3 fatty acid supplements; individuals with conditions causing oxidative stress such as hypertension, atherosclerosis, Parkinsonism, Alzheimer's disease, inflammatory conditions, chronic fatigue syndrome, asthma, or male infertility; patients with T2DM who have other macro- or microvascular complications or any ocular disease affecting ocular circulation (e.g., glaucoma, age-related macular degeneration, retinal vascular occlusion, or inherited macular disease); patients over 75 years of age; pregnant women; smokers; and alcoholics were excluded from the study.

Clinical Examination: Anthropometric measurements including height and weight was taken according to standardized procedures. Body Mass Index (BMI) was calculated as weight in kilograms divided by height in square meters. Fundoscopic examination was done by slit-lamp bio-microscopy using + 90 D noncontact lens and indirect ophthalmoscopy and presence or absence of DR was confirmed.

Laboratory Investigations: 5-10 ml of fasting venous blood sample was using aseptic techniques in serum separator tubes (with additive clot activator and gel for serum separation) or EDTA tubes. One aliquot of the separated serum was used immediately for assessment of biochemical parameters. EDTA blood sample was used to make a slide for haematological examination to compute NLR. Assessment of TAC and ceruloplasmin was done from the remaining serum stored at –20°C.

Estimation of routine biochemical parameters was done on fully automated Vitros 5600 Chemistry Analyzer (Ortho Diagnostics, Johnson &Johnson, USA) using Reflectance Photometry technology. Ceruloplasmin was analyzed on DxC 700 AU Chemistry Analyzer (Beckman coulter) using immunoturbidimetric method. Estimation of Complete blood count was done on Sysmex XN-10 Automated Haematology Analyzer. Estimation of Insulin and Ferritin was done on fully automated Vitros ECiQ using Chemiluminescence technology. Insulin resistance was calculated using the Homeostatic Model Assessment for Insulin Resistance (HOMA-IR), the formula for which is as follows:

$$\text{HOMA-IR} = \frac{\text{Fasting serum Insulin (µIU/ml)} \times \text{Fasting blood glucose (mg/dl)}}{405}$$

The Human Total Antioxidant Capacity (T-AOC) ELISA Kit (Catalog no. CK-bio-13742) (a manual

immunoassay for the quantitative determination of Total Antioxidant Capacity in human serum based on the principle of double antibody sandwich technology ELISA) was used for estimation of TAC). It has Standard curve range: 100µmol/L-4000µmol/L, Sensitivity: 10.0µmol/L, Intra-assay CV%: <7%, Inter-assay CV%: <10%.

Statistical Analysis

Quantitative variables were compared across the three groups using Mann-Whitney U test, ANOVA analysis and spearman's Rho correlation used to correlate quantitative parameters with each other. A p value of <0.05 was considered as statistically significant. The data was analysed using Statistical Package for the Social Sciences (SPSS) version 26.0.

RESULTS

The demographic characteristics of the study population are represented in Table 1. The mean ages±standard deviation of the T2DM with retinopathy, T2DM without retinopathy and control groups were 52 ± 8, 47 ± 10 and 27 ± 2 years respectively.

Table 1: Demographic and anthropometric characteristics among study groups

Parameter	Diabetics with Retinopathy (n=32)	Diabetics without Retinopathy (n=32)	Controls (n=32)
Age [mean (SD)]	52 (8)	47 (10)	27 (2)
Gender (%)			
Male	15 (46 %)	15 (46 %)	23 (72 %)
Female	17 (54 %)	17 (54 %)	9 (8 %)
BMI [mean (SD)]	26.14 (3.28)	25.83 (2.99)	24.03 (2.73)

Serum biochemical marker levels and antioxidant status are shown in Table 2. Diabetic subjects with retinopathy had higher FBG, HbA1c, Insulin (F), HOMA-IR, TC, TG, ferritin, ceruloplasmin and NLR levels than diabetics without retinopathy and control group. In contrast, HDL and TAC levels were higher in healthy control group.

Table 2: Biochemical parameters among study groups

Parameter [mean (SD)]	Diabetics with Retinopathy (n=32)	Diabetics without Retinopathy (n=32)	Controls (n=32)
Fasting blood glucose (mg/dl)	165.97 (74.70)	153.13 (57.06)	93.38 (10.41)
HbA1c (%)	8.78 (1.38)	7.95 (2.42)	4.60 (0.40)
Fasting Insulin (uIU/ml)	13.95 (11.06)	8.96 (6.77)	9.37 (5.42)
HOMA-IR	102.36 (99.15)	59.19 (46.78)	39.16 (23.87)
Total cholesterol (mg/dl)	180.81 (58.51)	162.22 (44.72)	144.34 (26.33)
HDL (mg/dl)	40.69 (10.42)	43.78 (14.24)	66.28 (19.33)
Triglycerides (mg/dl)	180.66 (116.93)	153.88 (83.32)	97.34 (21.93)
Ferritin (ng/dl)	108.19 (82.19)	66.91 (50.74)	40.38 (14.46)
Ceruloplasmin (mg/dl)	27.75 (5.19)	23.00 (3.69)	20.16 (3.51)
Neutrophils	65.58 (9.87)	62.28 (10.70)	62.06 (9.34)
Lymphocytes	25.75 (7.23)	29.63 (9.21)	30.65 (7.75)
NLR	2.86 (1.32)	2.45 (1.31)	2.22 (0.86)
TAC (mmol/L)	338.79 (80.98)	462.27 (80.51)	592.61 (107.96)

Mann-Whitney U test showed that HbA1c%, HOMA-IR, ferritin, ceruloplasmin, NLR and TAC values were significantly higher in the diabetics with retinopathy compared to control group, as shown in Table 3.

Table 3: Mann Whitney U test among diabetic retinopathy patients and healthy controls

	Group ID	N	Mean Rank	Sum of Ranks	p value
HbA1c (%)	DM+DR	32	48.47	1551	< 0.001
	Controls	32	16.53	529	
HOMA IR	DM+DR	32	41.69	1334	< 0.001
	Controls	32	23.31	746	
Ferritin(ng/ml)	DM+DR	32	43.06	1378	< 0.001
	Controls	32	21.94	702	
Ceruloplasmin(mg/dl)	DM+DR	32	45.44	1454	< 0.001
	Controls	32	19.56	626	
NLR	DM+DR	32	37.88	1212	0.021
	Controls	32	27.13	868	
TAC (µmol/l)	DM+DR	32	17.06	546	< 0.001
	Controls	32	47.94	1534	

The one-way ANOVA test was used to compare the means among three groups. A significant p value in the ANOVA test was found for all except NLR as shown in Table 4.

Table 4: ANOVA analysis across study groups

		Sum of Squares	df	Mean Square	F	p value
HbA1c (%)	Between Groups	320.65	2.00	160.32	58.43	< 0.001
	Within Groups	255.19	93.00	2.74		
HOMA IR	Between Groups	66751.91	2.00	33375.95	7.95	0.001
	Within Groups	390283.24	93.00	4196.59		
Ferritin(ng/ml)	Between Groups	74736.89	2	37368.44	11.75	< 0.001
	Within Groups	295721.09	93	3179.79		
Ceruloplasmin(mg/dl)	Between Groups	942.02	2	471.01	26.73	< 0.001
	Within Groups	1638.21	93	17.61		
NLR	Between Groups	6.72	2	3.36	2.39	0.097
	Within Groups	130.59	93	1.40		
TAC (µmol/l)	Between Groups	1031064.08	2	515532.04	62.63	< 0.001
	Within Groups	765523.88	93	8231.44		

Spearman's Rho correlation (as shown in Table 5) presents the correlation coefficients and p-values, showing significant associations ($p < 0.05$) between most variables, with strong positive correlations among metabolic markers and inverse correlations for TAC with other key parameters.

Table 5: Spearman's Rho correlation

	HBA1C		HOMA IR		Ferritin		Ceruloplasmin		NLR		TAC	
	ρ	p value	ρ	p value	ρ	p value	ρ	p value	ρ	p value	ρ	p value
HBA1C	-	NA	0.329	0.001	0.487	< 0.001	0.394	< 0.001	0.189	0.066	-0.65	< 0.001
HOMA IR			-	NA	0.382	< 0.001	0.446	< 0.001	0.015	0.882	-0.358	< 0.001
Ferritin					-	NA	0.325	0.001	0.108	0.294	-0.401	<.001
Ceruloplasmin							-	NA	0.074	0.472	-0.514	<.001
NLR									-	NA	-0.22	0.031
TAC											-	NA

Correlation Curves

The scatter plots (Figure 1 to Figure 6) show the correlations between different pairs of biological markers. The graphs shows that ferritin, ceruloplasmin, NLR and TAC has positive correlation, while antioxidant capacity (TAC) has a negative correlation with ferritin, ceruloplasmin and NLR.

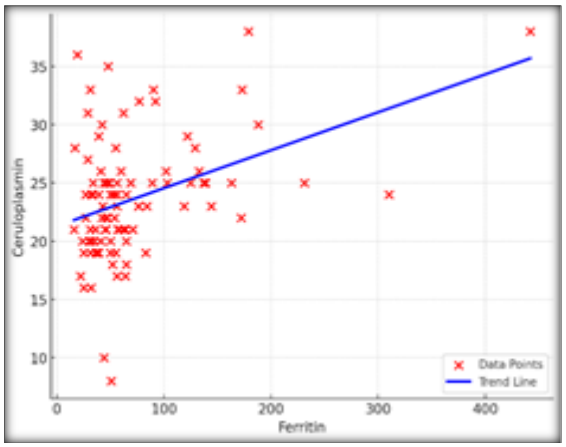


Figure 1: Correlation of Ferritin (ng/ml) and Ceruloplasmin (mg/dl)

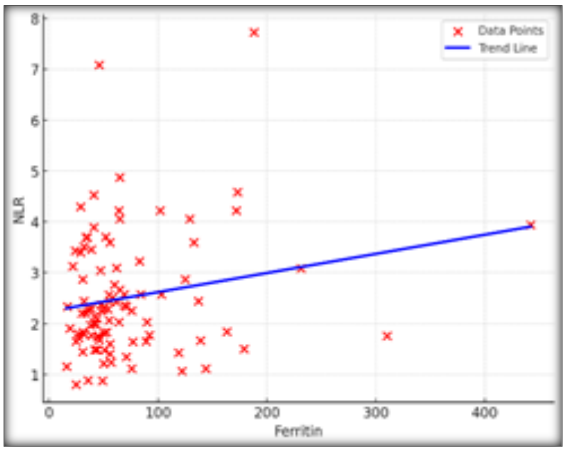


Figure 2: Correlation of Ferritin (ng/ml) and NLR

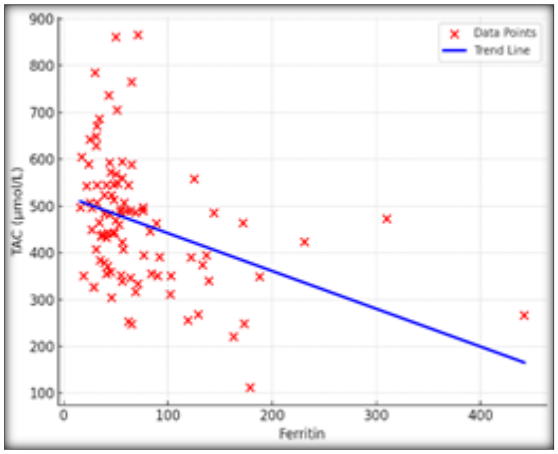


Figure 3: Correlation of Ferritin (ng/ml) and TAC (µmol/L)

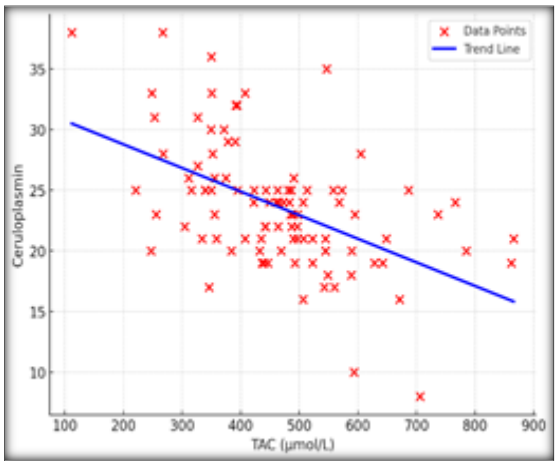


Figure 4: Correlation of Ceruloplasmin (mg/dl) and TAC (µmol/L)

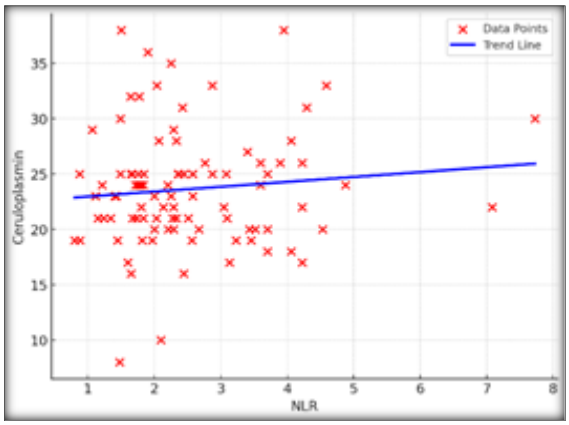


Figure 5: Correlation of Ceruloplasmin (mg/dl) and NLR

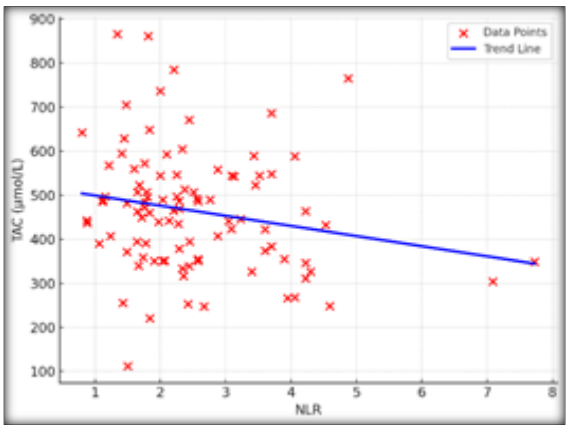
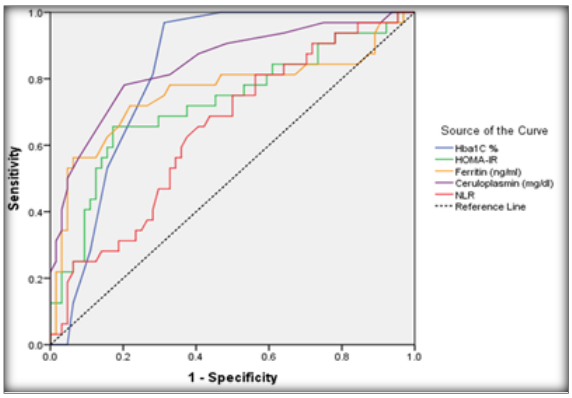


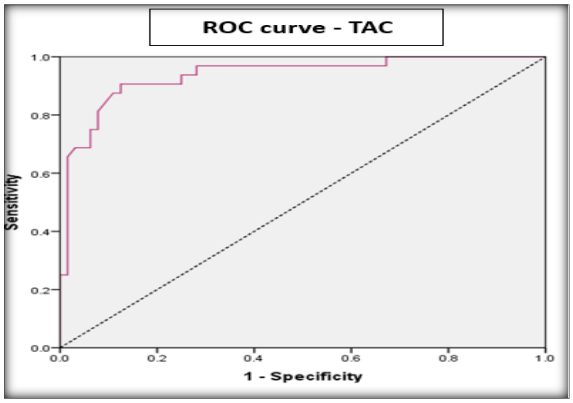
Figure 6: Correlation of NLR and TAC (µmol/L)

RECEIVER OPERATING CHARACTERISTICS CURVE (ROC CURVE) IN DIABETIC RETINOPATHY

ROC curve- HbA1c, HOMAIR, ferritin, ceruloplasmin, NLR



Area Under the ROC Curve	
Test Result Variable(s)	AUC
HBA1C (%)	0.826
HOMA-IR	0.727
Ferritin(ng/dl)	0.76
Ceruloplasmin(mg/dl)	0.844
NLR	0.646
TAC (µmol/l)	0.937



The ROC curves displayed above are of 6 parameters namely HbA1c, HOMA IR, ferritin, ceruloplasmin and TAC. Among them, HBA1C, HOMA IR, ferritin, ceruloplasmin and NLR are positively correlated with diabetic retinopathy while TAC is inversely correlated with diabetic retinopathy and hence the AUC for TAC is separately calculated.

In our current study, TAC is the best predictor of diabetic retinopathy with AUC of 0.937 and on the other hand NLR had the lowest significance with AUC of 0.646.

DISCUSSION

With the rising global prevalence of diabetes, lifestyle shifts, longer lifespans, and an aging population, the worldwide incidence and burden of diabetic retinopathy (DR) are projected to grow substantially in the coming decades from approximately 103 million cases in 2020 to 130 million by 2030, reaching 161 million by 2045.[15]

HbA1c% and HOMA-IR levels have shown a significant difference (p value <0.05) between the three groups, highlighting the combined impact of poor glucose control and insulin resistance in worsening diabetic retinopathy. Our findings showed that the pattern of HOMA-IR is predictable and expected as insulin resistance (IR) is one of the key pathophysiological findings in patients with diabetic retinopathy. A community-based study conducted by Tung TH et al,[16] had similarly concluded that DR was found to be strongly related to both baseline IR and HOMA-IR.

Elevated ferritin levels indicate oxidative stress, damaging insulin-producing pancreatic β cells and impairing insulin's regulation of glucose production in the liver. This leads to worsening of blood sugar control and contributes to eye complications via increased Vascular Endothelial Growth Factor (VEGF) activity.[17] Recent studies have identified the presence of a significant relationship between serum ferritin levels and fasting blood glucose (FBG) levels in patients with the disease, and these findings have shifted focus on the inflammatory markers of patients with type 2 DM. The present study showed a significant difference in serum ferritin levels between the three groups ($p < 0.001$). However other similar studies like the one conducted by Elis A V et al,[18] have not shown any significant difference between the three groups.

Ceruloplasmin is a prominent acute-phase reactant, playing a significant role in the pathogenesis of type 2 diabetes mellitus.[8] Our study has showed that the elevations in the levels of serum ceruloplasmin correspond with the severity of the disease, with significantly ($p < 0.001$) higher levels being recorded in T2DM with DR. Elevated ceruloplasmin levels may serve as a protective response against elevated circulating unbound Fe^{2+}, which promotes free radical-induced lipid peroxidation and intensifies oxidative stress.[19] Therefore, elevated plasma ceruloplasmin levels may indicate abnormally high oxidative stress. A study by Inoue et al. identified ceruloplasmin as a reliable marker of oxidative stress in diabetes mellitus (DM).[20]

The present study shows higher NLR in T2DM with retinopathy as compared to other two groups. These results are consistent with the findings of a study conducted by Ulu SM et al,[21] where NLR values of the diabetes patients were significantly higher than those of the healthy controls ($p < 0.001$) with DR patients showing higher values than those without DR ($p < 0.001$). Increased neutrophil-to-lymphocyte ratio (NLR) is linked to both the presence and severity of diabetic retinopathy (DR), positioning it as a potential biomarker for identifying high-risk patients and tracking disease progression, as inflammation contributes to retinal vascular damage in DR. [10]

In diabetic retinopathy, excessive reactive oxygen species (ROS) can overwhelm the body's antioxidant defences, resulting in reduced total antioxidant capacity (TAC). Consequently, low TAC levels in diabetic patients may serve as a biomarker indicating the severity or risk of developing retinopathy.[12] In the present study, the serum TAC levels showed a significant difference ($p < 0.001$) amongst all the three groups and TAC levels in healthy controls were significantly higher than in diabetic patients without retinopathy. Khallili K et al,[14] reported similar results in the three groups.

In the present study, there is positive correlation of HBA1C, ferritin, ceruloplasmin and NLR while TAC is inversely correlated with T2DM with retinopathy.

On using ROC analysis, it was found that TAC is the best predictor of diabetic retinopathy with AUC of 0.93. The area under curve for other parameters are ceruloplasmin (AUC = 0.844), ferritin (0.760) and NLR (0.646). Therefore, a decrease in TAC level coupled with elevated levels of ceruloplasmin and ferritin is a good indicator of diabetic retinopathy.

CONCLUSION

This study demonstrates that HbA1c, ferritin, ceruloplasmin and NLR are positively correlated

while TAC is inversely correlated with diabetic retinopathy. Elevated levels of ceruloplasmin and ferritin, along with reduced TAC, are strong indicators of DR and the three in conjunction may be used as a diagnostic tool to predict the occurrence of retinopathy.

REFERENCES

1. Flaxman SR, Bourne RR, Resnikoff S, Ackland P, Braithwaite T, Cicinelli MV et al. Global causes of blindness and distance vision impairment 1990–2020: a systematic review and meta-analysis. The Lancet Global Health. 2017 Dec 1;5(12):e1221-34..
2. Bokhary K, Aljaser F, Abudawood M, Tabassum H, Bakhsh A, Alhammad S, et al. Role of Oxidative Stress and Severity of Diabetic Retinopathy in Type 1 and Type 2 Diabetes. Ophthalmic Res. 2021;64(4):613-621.
3. Ung L, Pattamatta U, Carnt N, Wilkinson-Berka JL, Liew G, White AJ. Oxidative stress and reactive oxygen species: a review of their role in ocular disease. Clinical Science. 2017 Dec 4;131(24):2865-83.Lechner, J.; O'Leary, O.E.; Stitt, A.W. The pathology associated with diabetic retinopathy. Vision Res. 2017, 139, 7–14.
4. Lechner J, O'Leary OE, Stitt AW. The pathology associated with diabetic retinopathy. Vision research. 2017 Oct 1;139:7-14.
5. Kusuhara S, Fukushima Y, Ogura S, Inoue N, Uemura A. Pathophysiology of diabetic retinopathy: the old and the new. Diabetes & metabolism journal. 2018 Oct 22;42(5):364.
6. Deore AB, Sapakal VD, Naikwade NS. Role of oxidative stress in pathogenesis of diabetes and its complications. Pharmacologyonline. 2011;2:603-21.
7. Farhan M, Ahmed U, Anwar M K. Association of Serum ferritin and CRP levels with development and severity of diabetic retinopathy. Pakistan Journal of Physiology. 2017 Dec 31;13(4):11-4.
8. Mohiuddin SS, Manjrekar P. Role of ceruloplasmin as a low grade chronic inflammatory marker and activated innate immune system in pathogenesis of diabetes mellitus. J. Diabetes Metab. Disord. Control. 2018;5:148-53.
9. Cai J, Boulton M. The pathogenesis of diabetic retinopathy: old concepts and new questions. Eye (Lond). 2002 May;16(3):242-60.
10. Dascalu AM, Georgescu A, Costea AC, Tribus L, El Youssoufi A, Serban D, et al. Association Between Neutrophil-to-Lymphocyte Ratio (NLR) and Platelet-to-Lymphocyte Ratio (PLR) With Diabetic Retinopathy in Type 2 Diabetic Patients. Cureus. 2023 Nov 9;15(11): e48581.
11. Rani AJ, Mythili SV. Study on total antioxidant status in relation to oxidative stress in type 2 diabetes mellitus. J Clin Diagn Res. 2014 Mar;8(3):108-10.
12. Siemianowicz K, Gminski J, Telega A, Wójcik A, Posielezna B, Grabowska-Bochenek R, et al. Blood antioxidant parameters in patients with diabetic retinopathy. Int J Mol Med. 2004 Sep;14(3):433-7.
13. Suzuki S, Hinokio Y, Komatu K, Ohtomo M, Onoda M, Hirai S, et al. Oxidative damage to mitochondrial DNA and its relationship to diabetic complications. Diabetes Res Clin Pract. 1999 Sep;45(2-3):161-8.
14. Khalili F, Vaisi-Raygani A, Shakiba E, Kohsari M, Dehbani M, Naseri R, et al. Oxidative stress parameters and keap 1 variants in T2DM: Association with T2DM, diabetic neuropathy, diabetic retinopathy, and obesity. J Clin Lab Anal. 2022 Jan;36(1):e24163.
15. Teo ZL, Tham Y-C, Yu M, Chee ML, Rim TH, Cheung N, et al. Global prevalence of diabetic retinopathy and projection of burden through 2045: Systematic review and meta-analysis. Ophthalmology (2021) 128:1580–91.
16. Tung TH, Shih HC, Tsai ST, Chou P, Chen SJ, Lee FL, Chuang SY, Liu JH. A community-based study of the relationship between insulin resistance/beta-cell dysfunction and diabetic retinopathy among type II diabetics in Kinmen, Taiwan. Ophthalmic epidemiology. 2007 Jan 1;14(3):148-54.
17. Son NE. Influence of ferritin levels and inflammatory markers on HbA1c in the Type 2 Diabetes mellitus patients. Pakistan journal of medical sciences. 2019 Jul;35(4):1030.
18. Elis A, Ferencz JR, Gilady G, Livne A, Assia EI, Lishner M. Is serum ferritin high in patients with diabetic retinopathy? A controlled study. Endocrine research. 2004 Jan 1;30(2):141-7.
19. Daimon M, Susa S, Yamatani K, Manaka H, Hama K, Kimura M et al. Hyperglycemia is a factor for an increase in serum ceruloplasmin in type 2 diabetes. Diabetes care. 1998 Sep 1;21(9):1525-8.
20. Inoue K, Sakano N, Ogino K, Sato Y, Wang DH, Kubo M, Takahashi H, Kanbara S, Miyatake N. Relationship between ceruloplasmin and oxidative biomarkers including ferritin among healthy Japanese. journal of clinical biochemistry and nutrition. 2013;52(2):160-6.
21. Ulu SM, Dogan M, Ahsen A, Altug A, Demir K, Acartürk G et al. Neutrophil-to-lymphocyte ratio as a quick and reliable predictive marker to diagnose the severity of diabetic retinopathy. Diabetes technology & therapeutics. 2013 Nov 1;15(11):942-7.