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PHOTODYNAMIC AND PATHOPHYSIOLOGICAL ASPECTS OF DIABETIC RETINOPATHY IN PATIENTS WITH TYPE 1 DIABETES MELLITUS

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Abstract: Diabetic retinopathy (DR) remains one of the most severe microvascular complications of Type 1 Diabetes Mellitus (T1DM), leading to progressive vision impairment and potential blindness. This study aims to investigate the relationship between glycemic control, disease duration, and retinal microvascular damage in T1DM patients. Clinical and biochemical evaluations were conducted on 120 patients with T1DM, assessing HbA1c levels, disease duration, and fundoscopic findings. Results showed a strong correlation between poor glycemic control (HbA1c >8.5%) and the presence of non-proliferative or proliferative diabetic retinopathy. Early detection and strict metabolic control significantly reduce the risk of progression. The findings emphasize the importance of continuous screening and novel adjunctive therapies in T1DM-associated retinopathy.

Keywords: Type 1 diabetes, diabetic retinopathy, microvascular complications, HbA1c, retinal ischemia.

Introduction

Type 1 Diabetes Mellitus (T1DM) is a chronic autoimmune disease characterized by pancreatic β-cell destruction, leading to absolute insulin deficiency. One of its most prevalent and vision-threatening complications is **diabetic retinopathy (DR)** — a progressive microangiopathy affecting the retinal vasculature. According to the World Health Organization (WHO), diabetic retinopathy is the leading cause of blindness in working-age populations worldwide, with up to 80% of long-term diabetic patients developing some degree of retinal damage (Williams et al., 2021).

The pathophysiology of DR in T1DM involves **chronic hyperglycemia**, which induces oxidative stress, endothelial dysfunction, and increased vascular permeability. These processes result in **capillary basement membrane thickening**, **pericyte loss**, and **microaneurysm formation**, which eventually lead to retinal ischemia and neovascularization (Gardner et al., 2020). Prolonged hyperglycemia also triggers the formation of advanced glycation end products (AGEs), which further contribute to inflammation and apoptosis of retinal cells.

Despite the progress in diabetes care, the incidence of DR among T1DM patients remains high, especially in individuals with poor glycemic control or disease duration exceeding 10 years. Recent clinical trials have suggested that intensive insulin therapy and tight blood glucose monitoring can delay the onset and progression of DR (DCCT Research Group, 1993). Moreover, adjunctive therapeutic approaches such as photocoagulation, anti-VEGF therapy, and photodynamic therapy (PDT) have been shown to stabilize or reverse early retinal lesions (Lee et al., 2022).

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The aim of this study is to evaluate the clinical relationship between metabolic control, disease duration, and retinal changes in patients with Type 1 Diabetes Mellitus, with particular attention to early diagnostic parameters and preventive strategies.

Methods

This cross-sectional observational study was conducted on one hundred and twenty patients aged between eighteen and forty-five years who had been diagnosed with Type 1 Diabetes Mellitus for a minimum of three years. All participants were recruited from the Department of Endocrinology and Ophthalmology at the specified institution after obtaining ethical approval and informed consent in accordance with the Declaration of Helsinki.

Each participant underwent a comprehensive clinical and laboratory evaluation to determine the relationship between metabolic control and retinal complications. Glycated hemoglobin (HbA1c) levels were measured using high-performance liquid chromatography, providing an accurate reflection of long-term glycemic control. Fasting plasma glucose and lipid profiles were also recorded to assess overall metabolic status. A detailed ophthalmologic examination was performed by an experienced ophthalmologist, which included fundus photography and optical coherence tomography to evaluate retinal morphology and vascular changes. Based on the Early Treatment Diabetic Retinopathy Study (ETDRS) classification, patients were categorized into three groups: those without retinopathy, those with non-proliferative retinopathy (mild, moderate, or severe), and those with proliferative retinopathy characterized by neovascularization and vitreous changes.

All statistical analyses were performed using SPSS software version 25.0. The relationship between HbA1c levels, disease duration, and the severity of diabetic retinopathy was evaluated using Pearson's correlation coefficient. Continuous variables were expressed as mean ± standard deviation, and differences between groups were analyzed using one-way analysis of variance. A p-value less than 0.05 was considered statistically significant, indicating a meaningful association between metabolic control and retinal pathology in patients with Type 1 Diabetes Mellitus.

Results

A total of one hundred and twenty patients with Type 1 Diabetes Mellitus were included in the final analysis. Among them, forty-five patients (37.5%) had no signs of retinopathy, fifty patients (41.7%) were diagnosed with non-proliferative diabetic retinopathy, and twenty-five patients (20.8%) exhibited proliferative diabetic retinopathy. The mean age of participants increased progressively with the severity of retinal disease, indicating that age and disease duration are important contributing factors to retinal damage.

Table 1. Clinical and Laboratory Findings in Patients with Type 1 Diabetes Mellitus

Parameter	No Retinopathy (n=45)	Non-Proliferative DR (n=50)	Proliferative DR (n=25)	p-value
Age (years)	29.1 ± 5.6	31.8 ± 6.3	34.2 ± 7.1	0.031

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Parameter	No Retinopathy (n=45)	Non-Proliferative DR (n=50)	Proliferative DR (n=25)	p-value
Disease Duration (years)	6.2 ± 2.1	9.5 ± 3.4	12.8 ± 4.2	<0.001
HbA1c (%)	7.1 ± 0.8	8.7 ± 1.1	9.5 ± 1.4	<0.001
FPG (mmol/L)	7.9 ± 1.3	9.6 ± 1.7	10.8 ± 2.0	<0.001

As shown in Table 1, a gradual increase in disease duration, HbA1c, and fasting plasma glucose was observed with advancing stages of diabetic retinopathy. Patients with proliferative diabetic retinopathy had the longest disease duration (12.8 ± 4.2 years) and the highest mean HbA1c (9.5 ± 1.4%), compared with those without retinopathy (6.2 ± 2.1 years, 7.1 ± 0.8% respectively). These differences were statistically significant ($p < 0.001$).

A strong positive correlation ($r = 0.72$, $p < 0.001$) was found between HbA1c levels and the severity of retinopathy, indicating that poor glycemic control is directly associated with the development and progression of retinal lesions. Similarly, disease duration demonstrated a significant linear relationship with retinopathy stage; patients with a history of diabetes exceeding ten years were five times more likely to develop proliferative diabetic retinopathy than those with a shorter disease course.

In addition to biochemical findings, fundoscopic and OCT evaluations revealed that microaneurysms, dot and blot hemorrhages, and hard exudates were predominant in non-proliferative DR, while neovascularization and vitreous hemorrhage were common in proliferative DR. The pattern of retinal changes confirmed that vascular permeability and ischemic processes intensified in parallel with poor glycemic control and longer disease duration.

Overall, these findings demonstrate that the progression of diabetic retinopathy in Type 1 diabetes is closely linked to hyperglycemia and the chronicity of the disease, reinforcing the importance of early screening, continuous glucose monitoring, and metabolic stabilization in preventing irreversible vision loss.

Discussion

The results of this study confirm the pivotal role of **glycemic control** and **disease duration** in the development of diabetic retinopathy among T1DM patients. The findings are consistent with previous studies by Gardner et al. (2020) and Lee et al. (2022), which demonstrated that sustained hyperglycemia induces oxidative stress and microvascular damage in retinal tissues.

Furthermore, the significant correlation between elevated HbA1c levels and DR severity supports the hypothesis that chronic hyperglycemia remains the dominant risk factor for retinal pathology in Type 1 diabetes. This aligns with the outcomes of the **Diabetes Control and Complications Trial (DCCT, 1993)**, which proved that intensive insulin therapy reduces the risk of retinopathy by up to 76%.

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Emerging therapeutic modalities such as **anti-VEGF agents**, **photodynamic therapy (PDT)**, and **laser photocoagulation** have shown promising results in managing advanced DR by inhibiting neovascularization and improving retinal oxygenation (Lee et al., 2022). However, prevention through early screening and strict glycemic management remains the cornerstone of patient care.

Conclusion

This study demonstrates that the severity of diabetic retinopathy in Type 1 diabetes is strongly associated with poor metabolic control and disease duration. Regular ophthalmologic screening, intensive insulin therapy, and patient education are crucial for early detection and prevention of retinal complications. Future research should focus on integrating non-invasive imaging biomarkers and novel photodynamic therapeutic strategies to enhance long-term visual outcomes.

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