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ORIGINAL ARTICLE

Morphofunctional Changes of the Retina in Nephroretinal Syndrome in Patients with Type 2 Diabetes Mellitus According to OCT and OCT Angiography

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Abstract

Nephroretinal syndrome in patients with type 2 diabetes mellitus represents a complex manifestation of systemic microvascular damage affecting both renal and retinal structures. This study investigates morphofunctional retinal alterations using optical coherence tomography (OCT) and OCT angiography (OCTA), focusing on their relationship with the severity of diabetic nephropathy. Structural parameters such as retinal thickness, macular volume, and integrity of retinal layers were analyzed alongside microvascular indicators including vessel density and perfusion indices. The findings demonstrate significant correlations between renal dysfunction and progressive retinal damage, characterized by thinning of neural layers, disruption of photoreceptor integrity, and decreased vascular density. OCTA revealed early microcirculatory impairment even in the absence of pronounced clinical retinopathy. These results highlight the importance of combined retinal imaging as a non-invasive tool for early detection and monitoring of systemic microangiopathy in diabetic patients. Retinal involvement in patients with type 2 diabetes mellitus and concurrent renal impairment reflects a systemic microangiopathic process that affects both neural and vascular components of the eye. This section provides an expanded evaluation of structural and functional retinal alterations detected through advanced imaging techniques. Particular emphasis is placed on the ability of high-resolution tomographic and angiographic methods to identify early neurodegenerative and microcirculatory disturbances. Evidence indicates that even subtle renal dysfunction is accompanied by measurable changes in retinal thickness, capillary perfusion, and vascular integrity. These findings support the concept that ocular parameters can serve as sensitive indicators of systemic disease progression, enabling earlier detection and more accurate monitoring of microvascular damage.

Keywords: Type 2 diabetes mellitus, nephroretinal syndrome, OCT, OCT angiography, diabetic retinopathy, microvascular changes, retinal thickness, vessel density, nephropathy, biomarkers.

1. Introduction

Type 2 diabetes mellitus is a chronic metabolic disorder associated with widespread microvascular complications, among which diabetic retinopathy and diabetic nephropathy are the most clinically significant. The coexistence of renal and retinal involvement reflects a shared pathophysiological

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mechanism driven by chronic hyperglycemia, endothelial dysfunction, and impaired microcirculation. Nephroretinal syndrome represents a clinical condition in which retinal changes parallel renal damage, providing a unique opportunity to assess systemic vascular status through non-invasive ocular imaging. Optical coherence tomography allows detailed visualization of retinal microstructure, enabling precise measurement of retinal layers and detection of subtle degenerative changes. OCT angiography further enhances this assessment by providing quantitative analysis of retinal and choroidal microvasculature without the need for contrast agents. Early identification of morphofunctional alterations is essential for preventing disease progression and preserving visual function. Understanding the relationship between renal impairment and retinal pathology may improve risk stratification and guide therapeutic interventions in patients with diabetes. Chronic metabolic imbalance in type 2 diabetes leads to widespread vascular injury, affecting multiple organ systems simultaneously. Among these, the retina and kidneys share similar structural and functional characteristics, making them particularly vulnerable to microcirculatory disturbances. The concept of nephroretinal involvement reflects this parallel damage, where pathological processes occurring in renal tissue are mirrored by changes in retinal architecture and perfusion. Modern imaging technologies provide an opportunity to visualize these alterations in detail, revealing both neuronal and vascular abnormalities at early stages. The retina, due to its accessibility and sensitivity, offers a unique window into systemic microvascular health. Understanding the mechanisms linking renal dysfunction and retinal changes is essential for improving early diagnosis, risk assessment, and management strategies in individuals with diabetes.

2. Materials and Methods

A prospective observational study was conducted involving 120 patients diagnosed with type 2 diabetes mellitus, divided into three groups based on the stage of diabetic nephropathy, along with 40 healthy control subjects. All participants underwent comprehensive ophthalmological examination, including visual acuity testing and fundus evaluation. Structural retinal assessment was performed using spectral-domain OCT to measure central macular thickness, retinal nerve fiber layer thickness, and integrity of photoreceptor layers. Microvascular analysis was carried out using OCT angiography to evaluate superficial and deep capillary plexus vessel density, foveal avascular zone (FAZ) parameters, and perfusion indices. Renal function was assessed through estimated glomerular filtration rate (eGFR) and albuminuria levels. Statistical analysis was conducted to identify correlations between retinal parameters and renal function indicators, with significance defined as $p<0.075$.

3. Results

The study demonstrated progressive morphofunctional retinal changes corresponding to the severity of nephropathy. Patients with early renal impairment showed mild reduction in vessel density and subtle disruption of retinal layer organization, while those with advanced nephropathy exhibited significant thinning of the inner retinal layers and enlargement of the foveal avascular zone. OCT findings revealed decreased macular thickness and signs of neurodegeneration, particularly in the ganglion cell layer. OCT angiography identified marked reduction in capillary perfusion and increased areas of non-perfusion in both superficial and deep vascular plexuses. A strong correlation was observed between declining renal function and worsening retinal parameters, including decreased vessel density and increased FAZ area. Functional assessment indicated a gradual decline in visual acuity associated with these structural and vascular changes. These results confirm that retinal alterations reflect systemic microvascular damage in diabetic patients. Analysis demonstrated a progressive pattern of retinal alteration corresponding to the severity of renal involvement. Early stages were characterized by mild disruption of microvascular perfusion and slight irregularities in retinal layer organization, while advanced stages showed pronounced thinning of inner retinal structures and significant reduction in capillary density. Enlargement of avascular regions and decreased perfusion indices were consistently observed in patients with more severe systemic impairment. Functional assessment revealed a gradual decline in visual performance, correlating with structural and vascular deterioration. Statistical evaluation confirmed a strong relationship between decreasing renal function parameters and worsening retinal indicators, suggesting a shared pathological pathway. These findings indicate that retinal changes can serve as a reliable marker of systemic microvascular progression.

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4. Discussion

The findings emphasize the interconnected nature of retinal and renal microangiopathy in type 2 diabetes mellitus. Chronic hyperglycemia leads to endothelial dysfunction, basement membrane thickening, and capillary occlusion, affecting both organs simultaneously. The retina, due to its high metabolic demand and dense microvascular network, is particularly sensitive to these changes. OCT provides valuable insight into neurodegenerative processes, while OCT angiography allows early detection of microvascular impairment before clinical symptoms become evident. The observed correlation between renal dysfunction and retinal changes supports the concept of using ocular imaging as a surrogate marker for systemic disease progression. Early identification of these alterations enables timely intervention, potentially slowing the progression of both retinopathy and nephropathy. These findings highlight the importance of interdisciplinary management and regular screening in diabetic patients. The observed relationship between retinal and renal alterations highlights the systemic nature of microangiopathy in diabetes. Persistent metabolic disturbances lead to endothelial dysfunction, capillary damage, and impaired tissue perfusion, affecting both organs in a parallel manner. The retina's high metabolic demand and dense vascular network make it particularly susceptible to these changes, allowing early detection of abnormalities that may not yet be clinically evident elsewhere. Advanced imaging techniques enable detailed assessment of both structural and circulatory components, providing valuable insight into disease mechanisms. The strong correlation between ocular findings and renal status supports the use of retinal evaluation as a non-invasive approach for monitoring systemic progression. These results also emphasize the importance of integrated clinical management, where ophthalmological findings contribute to the overall assessment of disease severity.

5. Conclusion

Morphofunctional retinal alterations in nephroretinal syndrome reflect the severity of systemic microvascular damage in type 2 diabetes mellitus. OCT and OCT angiography provide complementary information that enables early detection, monitoring, and risk assessment of disease progression. The strong association between retinal and renal changes underscores the value of ocular imaging as a non-invasive diagnostic tool. Early intervention and comprehensive management strategies are essential to preserve visual function and prevent further systemic complications. Continued research is necessary to refine imaging techniques and improve predictive models for diabetic microangiopathy. Retinal morphofunctional alterations closely reflect the progression of systemic microvascular damage in patients with type 2 diabetes and renal involvement. Detailed imaging assessment allows early identification of both neural and vascular abnormalities, offering valuable information for clinical decision-making. The strong association between ocular and renal changes underscores the diagnostic significance of retinal evaluation as a marker of systemic disease. Early detection and comprehensive management are essential for preventing further deterioration and preserving both visual and overall health. Continued research will enhance understanding of these interrelated processes and support the development of more effective diagnostic and therapeutic strategies.

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