ORIGINAL RESEARCH PAPER

Biochemistry

EVALUATION OF MICROALBUMINURIA AND MALONDIALDEHYDE IN DIABETIC NEPHROPATHY

KEY WORDS:

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INTRODUCTION

Diabetic nephropathy (DN) is a major microvascular complication of diabetes mellitus and a leading cause of end-stage renal disease worldwide. One of the earliest clinical indicators of DN is microalbuminuria, which reflects subtle yet progressive renal injury. The pathogenesis of DN is multifactorial, involving hemodynamic alterations, metabolic disturbances, and inflammatory as well as oxidative mechanisms. Among these, oxidative stress—a state characterized by an imbalance between the production of reactive oxygen species (ROS) and the antioxidant defense system—plays a pivotal role in the initiation and progression of renal damage.

Hyperglycemia-induced oxidative stress leads to excessive generation of ROS, resulting in cellular and molecular damage to glomerular and tubular structures. One of the major consequences of ROS activity is lipid peroxidation, which compromises membrane integrity and cellular function. Malondialdehyde (MDA), a stable end product of polyunsaturated fatty acid peroxidation, is widely recognized as a sensitive and reliable biomarker of oxidative stress. Elevated MDA levels indicate enhanced lipid peroxidation and have been closely associated with the degree of oxidative injury in various pathological conditions, including DN.

Given the diagnostic and prognostic value of MDA, its estimation provides meaningful insights into the oxidative status of individuals with diabetes. Understanding the association between microalbuminuria and MDA can help elucidate the contribution of oxidative pathways in the early stages of DN. Such insights may further support the development of targeted therapeutic interventions aimed at reducing oxidative stress, thereby preventing or delaying the progression of diabetic nephropathy. The aim of the present study was to evaluate the levels of microalbuminuria and MDA and to find the association between them.

MATERIALS AND METHODS

A cross-sectional study was conducted in the Department of Biochemistry, Belagavi Institute of Medical Sciences (BIMS), Belagavi, to assess the relationship between microalbuminuria and oxidative stress marker Malondialdehyde (MDA) in patients with diabetic nephropathy (DN). The study involved 240 patients clinically diagnosed with DN, aged between 30 and 75 years. The study was approved by the Institutional Ethics Committee, and informed consent was obtained from all participants prior to inclusion.

The diagnosis of diabetic nephropathy was established by a Senior Physician from the Department of Medicine, BIMS, Belagavi. Confirmation was based on a combination of clinical evaluation, biochemical investigations, and ultrasonographic findings of the kidneys. The diagnostic criteria included persistent microalbuminuria along with evidence of long-standing diabetes mellitus.

Inclusion Criteria

- Patients aged 30–75 years with a confirmed diagnosis of diabetic nephropathy.
- Patients willing to provide written informed consent for participation in the study.

Exclusion Criteria

- Patients with non-diabetic renal diseases or acute kidney injury.
- Individuals suffering from hypertension, cardiovascular diseases, liver disorders, or other systemic inflammatory conditions known to alter oxidative stress parameters.
- Patients who were smokers, alcohol consumers, or undergoing treatment with antioxidant supplements, steroids, or nephrotoxic drugs.
- Pregnant and lactating women were also excluded from the study.

Sample Collection

Fasting blood samples and spot urine samples were collected from each participant under aseptic conditions. Serum and urine were separated immediately by centrifugation and stored appropriately until further biochemical analysis.

Estimation of Microalbuminuria

Microalbuminuria was evaluated by determining the albumin-to-creatinine ratio (ACR) in spot urine samples using the EM-200 semi-automated analyzer. The ACR values were expressed in mg/g of creatinine, and results were interpreted according to standard diagnostic cutoffs for micro-albuminuria.

Estimation of Malondialdehyde (MDA)

Serum MDA levels were measured manually using the Thiobarbituric Acid Reactive Substances (TBARS) method as described by Kei Satoh et al. (1978). This colorimetric method quantifies the pink chromogen formed by the reaction of MDA with thiobarbituric acid under acidic and high-temperature conditions. The absorbance was read at 532 nm, and results were expressed in nmol/mL.

Statistical Analysis

All collected data were tabulated and statistically analyzed using SPSS software version 22. Descriptive statistics were expressed as mean ± standard deviation (SD). Correlation between microalbuminuria and MDA levels was analyzed using Pearson's correlation coefficient. A p-value < 0.05 was considered statistically significant.

RESULTS

The Present study was conducted in 240 DN patients. Table 1 shows the mean ± SD levels of microalbuminuria and MDA levels. Microalbuminuria was present in all patients with the mean value of 55.6 ± 18.9 µg/mL. The normal reference range of microalbuminuria was 30-300 µg/mL. The mean serum MDA concentration was found to be 7.9 ± 2.6 nmol/mL signifying elevated oxidative stress among the study population. The increased MDA levels reflect enhanced lipid peroxidation, suggesting that chronic hyperglycemia in diabetes leads to excessive production of reactive oxygen species (ROS), which in turn damages cellular membranes and accelerates nephron injury.

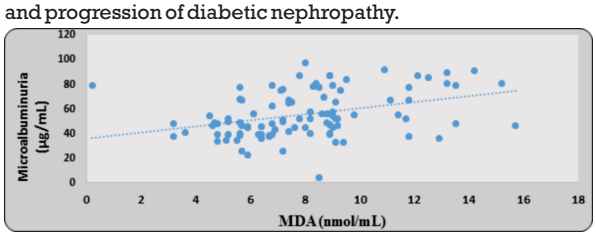
Table 1: Levels of Microalbuminuria and MDA in DN Patients

Study parameters	Mean ± SD	Reference Range
Microalbuminuria (µg/mL)	55.6 ± 18.9	30-300
MDA (nmol/mL)	7.9 ± 2.6	0.7- 1.5

Table 2: Correlation of Microalbuminuria with MDA in DN Patients

Parameters	r-value	p-value
MA / MDA	0.343	< 0.001**

Table 2 shows the correlation of microalbuminuria with oxidative stress markers in DN patients. There was highly significant positive correlation between microalbuminuria and MDA with the p-vaue of <0.001 and r-value of 0.34. This strong statistical association indicates that as oxidative stress increases, the extent of renal damage also intensifies. The data thus support the hypothesis that lipid peroxidation and ROS-mediated injury play a crucial role in the pathogenesis and progression of diabetic nephropathy.



Graph1: Correlation Between Microalbuminuria and MDA

The Graph 1 shows the correlation of microalbuminuria and MDA. In the graph we can see the the levels of MDA increases with increasing microalbuminuria suggesting the positive association between them.

DISCUSSION

The present study investigated the association between microalbuminuria and the oxidative stress marker malondialdehyde (MDA) in patients with diabetic nephropathy (DN). The results revealed a highly significant positive correlation ($r = 0.343$, $p < 0.001$) between urinary microalbumin and serum MDA levels, indicating that oxidative stress increases in parallel with the progression of renal injury in diabetes. These findings highlight the crucial role of oxidative mechanisms in the pathogenesis and progression of DN.

Diabetic nephropathy develops as a consequence of chronic hyperglycemia, which triggers multiple metabolic and hemodynamic disturbances leading to renal damage. Persistent hyperglycemia promotes non-enzymatic glycation of proteins, resulting in the formation of advanced glycation end products (AGEs). These AGEs interact with their cellular receptors (RAGE), initiating signaling cascades that enhance the generation of reactive oxygen species (ROS) and induce oxidative stress within renal tissues. Excess ROS lead to lipid peroxidation, DNA fragmentation, and protein oxidation, which collectively damage glomerular cells, mesangial matrix, and tubular structures, culminating in albumin leakage into the urine.

In this study, elevated MDA levels reflect increased lipid peroxidation and oxidative membrane damage in diabetic patients with nephropathy. Similar observations have been reported by Forbes et al. (2008) and Brownlee (2005), who emphasized that oxidative stress plays a central role in the onset and progression of diabetic microvascular complications. El-Sayed et al. (2016) also demonstrated significantly higher MDA levels in diabetic patients with microalbuminuria compared to those without, further corroborating the present findings.

The presence of microalbuminuria serves as an early marker of glomerular injury and endothelial dysfunction. Elevated urinary albumin excretion is not only a hallmark of DN but also an indicator of systemic vascular damage. The observed increase in MDA levels among patients with microalbuminuria supports the notion that oxidative stress precedes and amplifies renal injury, possibly through the activation of inflammatory mediators, cytokines (such as IL-6 and TNF-α), and the renin–angiotensin system. This interplay perpetuates a cycle of oxidative and inflammatory damage, accelerating nephron loss.

The statistically significant correlation between MDA and microalbuminuria found in this study thus underscores the diagnostic and prognostic potential of oxidative stress markers in diabetic nephropathy. Regular monitoring of MDA or similar biomarkers, alongside microalbuminuria, may aid in early detection of renal impairment even before overt clinical symptoms appear. Moreover, these findings lend support to therapeutic strategies aimed at reducing oxidative stress, such as tight glycemic control, dietary antioxidants, and pharmacological agents like ACE inhibitors, ARBs, or antioxidant vitamins, which have been shown to mitigate ROS-mediated renal injury.

However, the present study has certain limitations. Being cross-sectional, it establishes association but not causality. Longitudinal studies with larger populations are warranted to confirm whether changes in MDA levels predict the onset or progression of DN. Additionally, incorporating other oxidative and inflammatory biomarkers would provide a more comprehensive understanding of the molecular mechanisms driving renal dysfunction in diabetes.

In conclusion, this study reinforces that oxidative stress plays a pivotal role in the development and progression of diabetic nephropathy. The observed positive correlation between microalbuminuria and MDA levels suggests that lipid peroxidation and ROS-mediated injury contribute significantly to glomerular damage. Early detection and targeted management of oxidative stress could therefore represent a key strategy in delaying or preventing diabetic renal complications.

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