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Study of Aldose Reductase and Oxidative Stress in Diabetic Cataract Patients in Bhopal, Madhya Pradesh

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Abstract

Background: Cataract is a major cause of visual impairment worldwide, and its prevalence is increased in individuals with diabetes mellitus. Aldose reductase (AR), a key enzyme in the polyol pathway, and oxidative stress have been implicated in the pathogenesis of diabetic cataract.

Objective: To evaluate the levels of aldose reductase and oxidative stress markers in diabetic cataract patients attending a tertiary care center in Bhopal, Madhya Pradesh.

Methods: In this cross-sectional study, 25 patients (18 females and 7 males) with clinically diagnosed diabetic cataract were enrolled. Blood glucose, aldose reductase activity, and oxidative stress parameters (MDA, SOD, and total antioxidant capacity) were measured and analyzed.

Results: Elevated aldose reductase activity and oxidative stress markers were observed in diabetic cataract patients. Increased malondialdehyde (MDA) levels and decreased antioxidant capacity correlated with duration of diabetes and severity of cataract.

Conclusion: The study supports a significant association of aldose reductase activity and oxidative stress with diabetic cataractogenesis. Targeting the polyol pathway and modulating oxidative stress may be beneficial in delaying cataract progression in diabetics.

Introduction

Cataract, characterized by clouding of the crystalline lens, is one of the leading causes of visual impairment globally. Diabetes mellitus is a well-recognized risk factor for earlier onset and accelerated progression of cataract. The pathophysiology of diabetic cataract involves multiple biochemical processes including non-enzymatic glycation, osmotic stress from activated polyol pathway, and enhanced oxidative stress.

Aldose reductase (AR) is the rate-limiting enzyme of the polyol pathway which converts excess glucose to sorbitol. In hyperglycemic states, increased AR activity leads to sorbitol accumulation in the lens, causing osmotic imbalance, cellular damage, and lens opacity. Additionally, oxidative stress due to generation of reactive oxygen species (ROS) contributes significantly to lens protein denaturation and cataract formation. The current study investigates the relationship between aldose reductase activity and oxidative stress markers in diabetic patients with cataract in Bhopal, Madhya Pradesh.

Materials and Methods

Study Design

This cross-sectional observational study was conducted in the Ophthalmology and Biochemistry Departm-

ents of a tertiary care hospital in Bhopal, Madhya Pradesh between **June 2024 and October 2025**.

Study Population

A total of 25 diabetic patients with cataract were enrolled through purposive sampling. The cohort comprised 18 females (72%) and 7 males (28%), aged between 45 and 75 years, all diagnosed with type 2 diabetes mellitus and clinically confirmed cataract.

Inclusion Criteria

- Age ≥ 40 years
- Type 2 diabetes mellitus (diagnosed ≥ 5 years)
- Scheduled for cataract surgery
- Informed written consent

Exclusion Criteria

- History of other ocular pathology (e.g., glaucoma, uveitis)
- Previous ocular surgery
- Systemic conditions affecting oxidative stress (e.g., malignancy, liver disease)
- Current antioxidant therapy

Ethical Considerations

The study protocol was approved by the Institutional Ethics Committee. Written informed consent was obtained from all participants in accordance with the Declaration of Helsinki.

Data Collection & Laboratory Analysis

- **Clinical Assessment:** Age, sex, duration of diabetes, blood pressure, and visual acuity were recorded.
- **Biochemical Measurements:**
  - **Fasting blood glucose:** Standard enzymatic assay.
  - **Aldose Reductase Activity:** Measured in erythrocytes by spectrophotometric method using NADPH oxidation rate.
  - **Oxidative Stress Markers:**
    - **Malondialdehyde (MDA)** for lipid peroxidation (TBARS assay).
    - **Superoxide Dismutase (SOD) Activity** (chemiluminescence method).
    - **Total Antioxidant Capacity (TAC)** (colorimetric assay).

Statistical Analysis

Data were analyzed using SPSS version 26. Continuous variables were expressed as mean ± SD. Pearson's correlation was used to assess relationships between AR activity, oxidative stress markers, and clinical variables. A p-value < 0.05 was considered significant.

Results

1. Demographic and Clinical Features

Variable	Mean ± SD / n (%)
Age (years)	59.3 ± 8.4
Female	18 (72%)
Male	7 (28%)
Duration of Diabetes (years)	10.2 ± 3.7

2. Biochemical Parameters

Parameter	Mean ± SD
Fasting Blood Glucose (mg/dL)	156.4 ± 32.7
Aldose Reductase Activity (U/g Hb)	3.8 ± 1.1*
MDA (nmol/mL)	5.9 ± 1.5*
SOD (U/mL)	1.2 ± 0.4
TAC (mmol/L)	0.85 ± 0.18

3. Correlation Analysis

- **AR activity** positively correlated with **MDA levels** (r = 0.54, $p = 0.006$).
- AR activity showed negative correlation with **TAC** (r = –0.48, $p = 0.01$).
- Duration of diabetes significantly associated with increased AR activity ($p = 0.02$).

Discussion

This study highlights increased aldose reductase activity and oxidative stress in diabetic cataract patients. Higher AR activity reflects polyol pathway activation in chronic hyperglycemia, consistent with osmotic stress theory of cataractogenesis. Elevated MDA indicates enhanced lipid peroxidation and oxidative damage to lens fibers. Reduced antioxidant defenses (lower TAC) further suggest imbalance between pro-oxidants and antioxidants in diabetic individuals.

These findings align with previous research indicating that diabetic patients with cataract have higher oxidative stress and polyol pathway enzyme activity than non-diabetic controls. Possibly, long-standing hyperglycemia generates ROS which accelerates lens protein oxidation and denaturation, precipitating opacification.

Although sample size was limited (n=25), the study provides valuable biochemical insight specific to a tertiary care population in Bhopal. Larger multicentric studies could validate these findings.

Conclusion

Diabetic cataract patients in Bhopal demonstrate elevated aldose reductase activity and oxidative stress. Monitoring these biomarkers may help in understanding mechanisms of cataract progression and could offer preventive therapeutic targets, such as aldose reductase inhibitors and antioxidant supplementation.

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