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Exploring electrolyte imbalances in cataractogenesis: A comparative analysis of sodium and potassium levels in diabetic and non-diabetic patients

Beatrice Choppara[1], Irigu Vijay Kumar[2], Aradhana Badam[3], Sara Sultana[4]

[1]Assistant Professor, Department of Ophthalmology, Government Medical College and General Hospital, Nalgonda, [2]Assistant Professor, Department of Biochemistry, Government Medical College and General Hospital, Suryapet, [3]Assistant Professor, Department of Biochemistry, Osmania Medical College and General Hospital, [4]Assistant Professor, Department of Ophthalmology, Sarojini Devi Eye Hospital, Hyderabad, Telangana, India

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ABSTRACT

Background: Cataract, a major cause of treatable blindness accounting for 80% of cases, arises from a complex etiology involving various factors. Diabetes notably expedites cataract development, and its potential interaction with electrolyte imbalances further enhances our understanding. **Aims and Objectives:** This study aimed to explore the concentrations of electrolytes, specifically sodium (Na^+) and potassium (K^+), in both serum and aqueous humor, and their potential implications in the pathogenesis of cataracts among individuals with diabetes. **Materials and Methods:** A comprehensive observational study encompassed a cohort of 100 cases, equally divided into diabetic and non-diabetic cataract patients. Gender distribution and age groups were established, focusing on individuals aged 40 years and above. Serum sodium (Na^+) and potassium (K^+) levels were compared against reference ranges, and statistical analyses included an unpaired Student's t-test and the Statistical Package for the Social Sciences 20 software. **Results:** Among diabetic cataract patients, serum sodium levels were notably elevated (149.2147 ± 2.71 meq/L) compared to non-diabetic counterparts (145.04 ± 2.25 meq/L), demonstrating high significance ($P<0.001$). Similarly, diabetic patients exhibited a marginal increase in serum potassium (4.1919 ± 0.5011) in contrast to non-diabetic patients (4.1264 ± 0.5124), with a non-significant P-value ($P<0.5$). Aqueous humor analysis revealed a substantial rise in both sodium and potassium levels among diabetic cataract cases, demonstrating high significance ($P<0.001$). **Conclusion:** This study presents compelling evidence of distinct electrolyte profiles, particularly sodium and potassium, between diabetic and non-diabetic cataract patients. Elevated serum and aqueous humor sodium levels in diabetics suggest a potential contributory role in cataractogenesis.

Key words: Cataract; Diabetes; Electrolytes; Sodium; Potassium; Aqueous humor; Pathogenesis

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INTRODUCTION

Cataract, a pervasive ocular disorder, is a primary contributor to treatable blindness and represents approximately 80% of all such cases worldwide[1,2] and characterized by the clouding of the eye's natural lens, cataracts impair vision, and significantly impact an individual's quality of life. Despite their prevalence, the exact pathogenesis of cataract formation is complex, involving a delicate interplay of genetic, environmental, and physiological factors.[3]

The lens of the eye is a complex, transparent structure responsible for focusing light onto the retina, thus facilitating clear vision. In the development of cataracts, the clarity of the lens becomes compromised as proteins

Address for Correspondence:
Dr. Sara Sultana, Assistant Professor, Department of Ophthalmology, Sarojini Devi Eye Hospital, Hyderabad, Telangana, India.
Mobile: +91-9848658832. **E-mail:** sarasultana771@gmail.com

within it denature and aggregate, leading to opacification. While age-related changes in lens fibers contribute to this formation, emerging research points to a broader range of influencers.

Diabetes, a well-established global health concern, has been increasingly recognized as a significant catalyst for cataractogenesis.[4,5] Beyond its association with metabolic abnormalities and vascular complications, diabetes appears to accelerate the onset and progression of cataracts.[6] This correlation is particularly concerning given the rising prevalence of diabetes, a significant public health challenge. Understanding the mechanisms underlying the relationship between diabetes and cataract development has potential implications for both clinical management and preventive strategies.[7]

A new aspect of this discussion is the potential impact of electrolyte imbalances on worsening cataract formation in diabetic individuals.[8,9] Electrolytes, including sodium (Na^+) and potassium (K^+), are essential for maintaining cellular homeostasis and physiological functions throughout the body.[10] Disruptions in electrolyte balance can lead to cellular stress, inflammation, and oxidative damage processes that are intricately linked to the development of various health conditions.[11]

The relationship between diabetes, electrolyte imbalances, and cataract development is interesting and worth studying. While we do not fully understand how these factors connect, recent studies are starting to explain their interactions. For instance, high blood sugar, common in diabetes, might affect the parts of lens cells that manage ions. This can upset the balance of salts in the lens, leading to cloudy vision.

Against this backdrop, the present study endeavors to examine the concentrations of sodium and potassium in serum and aqueous humor among individuals afflicted with both diabetic and non-diabetic cataracts. Through a comprehensive analysis of a cohort comprising 100 cases, equally distributed between diabetic and non-diabetic patients, this investigation aims to offer valuable insights into the potential involvement of electrolyte imbalances in the genesis of cataracts.

Aims and objectives

This study aims to quantify sodium and potassium levels in serum and aqueous humor, comparing diabetic and non-diabetic cataract patients. It seeks to evaluate correlations between electrolytes and cataract presence or severity, analyze gender or age differences, assess clinical significance against reference ranges, explore mechanisms linking electrolyte imbalances to cataractogenesis, enhance diabetes-related cataract insights, offer clinical implications, and establish a foundation for future intricate diabetes-electrolyte-cataract research.

MATERIALS AND METHODS

Study design

This comparative observational study was conducted at the Government Medical College and General Hospital, Suryapet, Telangana, India, from July 2022 to December 2022.

Sample size and selection

A total of 100 subjects participated, including 50 individuals diagnosed with diabetic cataracts and an equal number without diabetes, constituting the non-diabetic cataract group. Informed written consent was obtained from each participant, ensuring their understanding and willingness to participate.

Inclusion criteria

Age threshold

Participants aged 40 years and above were specifically targeted for inclusion. This age range was chosen to emphasize the investigation of age-related cataract development, a phenomenon that gains prominence with advancing age.

Cataract diagnosis

Individuals diagnosed with cataracts, irrespective of their diabetic status, were included. This encompassed both diabetic and non-diabetic patients, aiming to encompass a comprehensive spectrum of cataract cases.

Exclusion criteria

Medical conditions

Participants with documented histories of hypertension, liver disease, cardiac disease, or renal disease were excluded. These conditions are recognized for their potential to disrupt electrolyte balance, which could potentially confound the study's examination of electrolyte imbalances and their relationship with cataract development.

Ocular factors

Individuals with a history of ocular trauma, steroid intake, glaucoma, uveitis, or chronic use of topical medications were excluded. These factors were deemed exclusionary due to their potential to introduce complexities that might interfere with the study's focus on electrolyte-related influences on cataract formation.

Procedure for Electrolyte Collection

Blood sample collection for serum electrolyte measurement

A total of 2 mL of venous blood were meticulously collected from each study participant's arm using sterile techniques. The blood samples were collected in appropriate anticoagulant-free tubes to prevent interference with electrolyte measurements. These blood samples were then carefully transported to the biochemistry laboratory for further processing.

Collection of aqueous humor

In preparation for cataract surgery, patients received a peribulbar injection to ensure patient comfort and stability during the procedure. Following the injection, patients underwent cataract surgery using a small incision cataract surgery (SICS) approach. Before proceeding with the cataract surgery, 0.2 mL of aqueous humor was aspirated from the anterior chamber using a sterile tuberculin syringe. To maintain the stability of the anterior chamber and ensure accurate collection, viscoelastic material was injected into the chamber after aspirating the aqueous humor.

Laboratory analysis of electrolytes

The collected venous blood samples were immediately transported to the biochemistry laboratory for analysis. In the biochemistry laboratory, the serum electrolyte levels were estimated using the ion-selective electrode technique. The concentrations of sodium (Na^+), potassium (K^+), and chloride (Cl^-) ions were determined using the ion-selective electrode method, which allows for accurate and precise measurement of electrolyte concentrations in biological samples. The ion-selective electrode technique involves measuring the potential difference between specific ion-selective electrodes and a reference electrode, allowing for the quantification of individual ion concentrations.

Aqueous Humor Analysis

The aspirated aqueous humor samples were also transported to the biochemistry laboratory. The sodium and potassium concentrations in the aqueous humor were analyzed using the same ion-selective electrode technique utilized for serum electrolyte measurements. This technique enables the precise quantification of sodium and potassium ions in aqueous humor samples.

Cataract surgery

Each patient underwent cataract surgery employing a SICS approach, complemented by posterior chamber intraocular lens implantation. This surgical procedure was conducted to address the cataract condition and restore visual acuity.

Statistical analysis

The collected data underwent rigorous statistical analysis. Descriptive statistics was employed to summarize demographic and clinical characteristics. The unpaired Student's t-test was utilized for comparing serum and aqueous humor electrolyte concentrations between diabetic and non-diabetic groups. Ethical considerations included ensuring patient confidentiality, obtaining informed consent, and adhering to ethical guidelines.

Ethical considerations

Before initiating the study, ethical approval was obtained from the Institutional Ethics Committee of Government Medical College, Suryapet. Informed written consent was obtained from each participant, elucidating the study's objectives, procedures, and potential risks. Patient privacy and confidentiality were strictly upheld throughout the study.

RESULTS

1. Patient demographics: Our study encompassed a total of 100 cases, equally distributed between individuals with diabetic cataracts and those with non-diabetic cataracts. Both groups consisted of individuals aged 40 and above. Within the diabetic cataract group, there were 17 males and 33 females. In contrast, the non-diabetic cataract group consisted of 14 males and 36 females (Tables 1 and 2).
2. Age analysis: The average age, accompanied by the standard deviation, for the diabetic cataract group was 61.76±6.07 years. For the non-diabetic cataract group, it was 66.52±6.01 years. The age-related difference between these two groups was not statistically significant, with a P>0.05 (Table 1).
3. Electrolyte analysis: For the purpose of our study, the reference ranges were defined as 135–145 meq/L for serum sodium and 3.5–5.5 meq/L for serum potassium. In our findings, the diabetic cataract group exhibited serum sodium levels of 149.2147±2.71 meq/L, notably higher than the 145.04±2.25 meq/L observed in the non-diabetic cataract group. This variation was statistically significant, as indicated by a P<0.001. In contrast, the serum potassium levels showcased a minor difference: 4.1919±0.5011 meq/L in the diabetic cataract group compared to 4.1264±0.5124 meq/L in the non-diabetic group. The statistical test for this difference produced a P<0.05, suggesting significance, although to a lesser degree than the sodium levels (Table 3).
4. Aqueous humor electrolyte analysis: for aqueous humor sodium levels, the diabetic cataract group exhibited a concentration of 160.6215±3.26 meq/L,

Table 1: Age distribution of patients

Age	No of patients	Percentage
41–50	8	0.08
51–60	31	0.31
61–70	34	0.34
71–80	16	0.16
>80	11	0.11

Table 2: Gender distribution of patients

Gender	No. of patients	Percentage
Male	31	0.31
Female	69	0.6966

Table 3: Comparision of serum sodium and potassium in diabetic cataract and non-diabetic cataract patients

Serum electrolytes	Diabetic cataract	Non-diabetic cataract	P-value
Serum sodium	149.2147±2.71	145.04±2.25	P<0.001
Serum potassium	4.1919±0.5011	4.1264±0.5124	P<0.05

while the non-diabetic cataract group showed levels of 157.4816±3.18 meq/L. This variation was statistically significant, with a P<0.001. Similarly, in the case of aqueous humor potassium levels, the diabetic cataract group measured 3.9314±0.4731 meq/L, whereas the non-diabetic cataract group had levels of 3.5864±0.4952 meq/L. The observed difference was statistically significant, with a P<0.001 (Table 4).

Table 4: Comparison of aqueous humor sodium and aqueous humor potassium in diabetic cataract and non-diabetic cataract patients

Aqueous humor electrolytes	Diabetic cataract	Non-diabetic cataract	P-value
Aqueous humor sodium	160.6215±3.26	157.4816±3.18	P<0.001
Aqueous humor potassium	3.9314±0.4731	3.5864±0.4952	P<0.001

DISCUSSION

Cataracts, which cause clouding of the lens, are a leading source of visual impairment. Diabetes mellitus is known to increase the risk of developing cataracts. Our study explored the possible connection between electrolyte imbalances and cataract formation in diabetic individuals, aiming to enhance our understanding of this complex relationship. Our findings support earlier research, highlighting the influence of both serum and aqueous humor electrolyte levels on the progression of cataracts in diabetic patients.

Consistent with prior investigations, we observed that cataracts tend to develop earlier in diabetic individuals compared to non-diabetics (Jadav et al.,[1] Harding et al.[2]). Having diabetes for a longer time and poor control of the condition both raised the risk of developing cataracts (Kahn et al.[3]). Our study revealed notable gender differences, with a higher prevalence of diabetic cataract among females, in accordance with earlier studies (Jadav et al.,[1] Harding et al.[2]).

The aqueous humor plays a vital role in lens nutrition, and any electrolyte imbalance in serum can potentially influence the aqueous humor composition, subsequently impacting lens metabolism. As reported by Adler, disturbances in aqueous humor electrolyte levels may lead to cataract formation (Adler[7]). We found significant elevations in serum and aqueous humor sodium levels in diabetic cataract patients, consistent with previous research linking raised serum sodium to cationic imbalances and cataractogenesis (Adler;[7] Adiga et al.[14]).

Moreover, our study concurred with literature indicating a relationship between diabetes and altered serum electrolyte concentrations, particularly sodium and potassium (Liamis et al.,[8] Komjati et al.[9]). Diabetes-related hyperglycemia can induce serum osmolality changes,[16] resulting in water movement out of cells and a subsequent reduction in serum sodium levels (Liamis et al.[8]). Furthermore, hypernatremia in diabetes has been attributed to endocrine dysfunction (Komjati et al.[9]). We observed higher serum sodium levels in diabetic cataract patients compared to non-diabetics, supporting the link between diabetes-associated electrolyte disturbances and cataract development.

Our investigation also revealed elevated serum potassium levels in diabetic cataract patients. Hyperkalemia in diabetes is attributed to the redistribution of potassium from intracellular[11] to extracellular compartments (Palmer[12]). Interestingly, the lens maintains a delicate balance of high potassium and low sodium concentrations, achieved through the Na-K ATPase pump.[13] Any disruption in serum electrolyte concentrations may directly affect aqueous humor electrolyte composition, impacting lens metabolism (Tasneem et al.[15]).

Our study's limitations include its cross-sectional design and potential confounding factors not accounted for in our analysis. However, our findings, in line with previous research, highlight the intricate relationship between diabetes, electrolyte imbalances, and cataractogenesis. Addressing electrolyte imbalances may offer new avenues for managing diabetic cataracts, complementing existing approaches to diabetes care and cataract prevention.

Limitations of the study

This study was confined to a small sample size, potentially reducing generalizability. The observational design does not establish causation between electrolyte imbalances and cataractogenesis. Potential confounding variables, such as duration of diabetes, dietary intake, or medications affecting electrolyte levels, were not controlled or accounted for in the analysis.

CONCLUSION

Our study underscores the significant impact of serum and aqueous humor electrolyte imbalances on cataract development in diabetic individuals. These findings contribute to the broader understanding of cataractogenesis in the context of diabetes and emphasize the potential clinical implications for managing cataract progression. Further research is warranted to unravel the precise mechanisms underlying the interplay between electrolytes and cataract formation, opening doors to innovative therapeutic interventions.

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Authors Contribution:
BC-Concept and design of the study, results interpretation, review of literature and preparing the first draft of manuscript. Statistical analysis and interpretation, revision of manuscript. **IVK-**Concept and design of the study, results interpretation, review of literature and preparing first draft of manuscript, revision of manuscript. **AB-**Review of literature and preparing first draft of manuscript. Statistical analysis and interpretation. **SS-**Concept and design of the study, results interpretation, review of literature and preparing first draft of manuscript. Statistical analysis and interpretation, revision of manuscript.

Work attributed to:
Government Medical College and General Hospital, Suryapet, Telangana, India.

Orcid ID:
Beatrice Choppara - https://orcid.org/0009-0009-5411-5317
Irigu Vijay Kumar - https://orcid.org/0009-0004-2349-0142
Aradhana Badam - https://orcid.org/0009-0006-8573-3044
Sara Sultana - https://orcid.org/0009-0009-8880-2000

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