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Original Article

Ophthalmology Section

Effects of Haemodialysis on Anterior Segment Parameters of the Eye in Patients with End-stage Renal Disease: A Cross-sectional Study

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ABSTRACT

Introduction: Ocular manifestations of Haemodialysis (HD) are one of the important causes of morbidity in End-stage Renal Disease (ESRD) patients. According to studies, the incidence rate of glaucoma in the dialysis group was higher than that in the non dialysis group. Angle-closure glaucoma was found to be more common, which depends on anterior chamber morphology.

Aim: To assess the effect of HD on Intraocular Pressure (IOP), Anterior Chamber Depth (ACD), and Lens Thickness (LT) in patients with ESRD.

Materials and Methods: This was a single-centre cross-sectional observational study conducted in the Department of Ophthalmology on 170 eyes of 87 patients undergoing HD for at least three months. The study was conducted between October 2020 and October 2022 at the Dialysis Centre of Bharati Vidyapeeth (DTU) Medical College and Hospital, Pune, Maharashtra, India. These patients underwent ophthalmological evaluation pre- and postdialysis. IOP, ACD, and LT were measured 30 minutes prior to and 30 minutes after the HD session. The paired t-test was used to compare differences in means, and a p-value of <0.05 was considered significant.

Results: The mean age of the study participants was 57.63±11.95 years. There was a decrease in mean ACD by 0.08±0.29 mm (p=0.0001) and an increase in mean LT by 0.06±0.42 mm (p-value=0.0001) postdialysis. The changes in IOP were variable and not statistically significant (p=0.45).

Conclusion: Postdialysis, a significant increase in LT was observed corresponding to a decrease in ACD. Although the change in IOP was variable, this change might be more significant in pre-existing narrow-angle patients undergoing dialysis. As a result, the present study underscores the urgency of refining screening protocols for HD patients to effectively address these identified ocular changes and associated risks.

Keywords: Anterior chamber depth, End stage renal disease, Glaucoma, Haemodialysis, Intraocular pressure, Lens thickness

INTRODUCTION

A growing global health issue, Chronic Kidney Disease (CKD), affects almost all body organs, including the eyes [1,2]. The fifth stage of CKD is ESRD, which is defined as a significant reduction in Glomerular Filtration Rate (GFR) to less than 15 mL/min [3]. The mainstay of treatment for ESRD is HD, which is based on the solute diffusion principle across a semi-permeable membrane, allowing metabolic waste products to move from the circulation into the dialysate, down a concentration gradient [4]. The reported incidence of ESRD is 151 per million people in an Indian population-based study. In India, the number of people receiving dialysis is around 55,000, and it is expanding at a rate of 10-20% annually [5,6].

Ocular abnormalities associated with HD are one of the important causes of morbidity in dialysis patients [2,3]. A study by Kianersi F has shown the persistence of certain ocular findings among ESRD patients undergoing HD, with a potential pathophysiological mechanism correlating with increased plasma Colloid Osmotic Pressure (COP), alterations in calcium and phosphorous levels during the uraemic state, and chronic inflammation [7]. Ocular abnormalities include changes in IOP associated with HD, corneal and conjunctival abnormalities, metastatic calcification, chronic inflammatory changes, cataracts, and retinal diseases (e.g., retinal detachment, macular leakage, retinal haemorrhage, and optic neuropathy) [7,8].

The change in IOP has been inconsistent [9,10]. A study by Caglayan M et al., has shown alterations in the irido-corneal angle, lens, and ocular perfusion of the cornea and lens [11]. Gracitelli CPB et al., studied ACD, lens position, and thickness as predictors for the high risk of developing glaucoma in HD patients [12].

In one population-based study, the incidence rate of glaucoma in the dialysis group was much higher, at 8.18 per 10,000 patients, compared to the non dialysis group (5.01 per 10,000 patients). Angle-closure glaucoma was significantly more common in dialysis patients [13]. The present study systematically evaluated changes in parameters such as ACD, LT, Central Corneal Thickness (CCT), and IOP before and after HD sessions. Thus, the findings of this research can help form a screening protocol that includes measurements of anterior segment parameters to identify dialysis patients at high risk for developing glaucoma.

The aim of the present study was to investigate and analyse the impact of HD treatment on various anterior segment parameters of the eye in individuals suffering from ESRD.

MATERIALS AND METHODS

The present study was a single centre cross-sectional, observational study conducted in the Department of Ophthalmology at Bharati Vidyapeeth (DTU) Medical College and Hospital over a period of two years from October 2020 to October 2022. After obtaining approval from the Institutional Ethics Committee (BVDUMC/IEC/33), written informed consent was obtained from the patients. The procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (Institutional) and with the Helsinki Declaration of 1975, revised in 2013 [14].

Sample size calculation: The sample size calculation was based on the results of a study by Chen H et al., with predialysis Standard Error (SE) of 0.420 converted to Standard Deviation (SD) of 3.98, and postdialysis SE of 0.476 converted to SD of 4.52. Assuming a pooled SD of 4.26 and an allowable error (mean difference) of

1.3, with 80% power and a 5% level of significance, the minimum sample size required was determined to be 168 [9]. A single-stage cluster sampling technique was used, involving patients with ESRD on dialysis.

Inclusion criteria: The study included patients aged 18 years and above, of either gender, who had been diagnosed with ESRD and were currently receiving HD treatment for at least three months of consistent therapy.

Exclusion criteria: Patients with any corneal pathology, diagnosed cases of glaucoma, and those with a prior history of ocular surgery (cataract/glaucoma surgery/laser peripheral iridotomy) or ocular trauma were excluded.

Study Procedure

Both eyes of 135 patients undergoing dialysis during the study period were evaluated after obtaining written informed consent. A total of 48 patients were excluded based on the exclusion criteria. The study was conducted on 170 eyes of 87 patients. Four pseudophakic eyes were excluded from the study.

All patients underwent four-hour HD sessions, three days per week, at a blood flow rate of 250 mL/min. Patients were treated using high-performance dialysers: 4008S-type Fresenius HD machine (Germany) using Fresenius F8 dialyser. Patient blood was dialysed against bicarbonate dialysate (1.5 mmol/L calcium). All patients had arteriovenous fistulas.

Thorough ophthalmic examination was performed, including best-corrected visual acuity using Snellen chart, slit lamp biomicroscopic examination of the anterior segment, and fundus examination using a 90D lens. ACD, LT, and CCT were evaluated using optical biometry with the IOL Master machine (Topcon Aalladin). IOP was measured using a Goldmann applanation tonometer (Optilasa S.L.). All examinations were conducted 30 minutes before the start of HD and repeated 30 minutes after the end of HD, and all data were recorded.

STATISTICAL ANALYSIS

Data was analysed using Statistical Packages for Social Sciences (SPSS) software version 25.0. Descriptive statistics were used to show continuous variables, and frequency and percentages were used for categorical variables. Paired t-test was used to test the mean difference between ACD, LT, CCT, and IOP pre- and post-HD. A p-value of <0.05 was considered significant.

RESULTS

The study examined the impact of HD on anterior segment parameters of the eye in individuals with ESRD. A total of 87 patients with ESRD undergoing HD were included, with a mean age of 57.63±11.95 years. Out of the 87 patients, 36 (41.38%) were females and 51 (58.62%) were males. The mean duration of dialysis in these patients was 2.88±1.76 years, ranging from 0.33 to 7 years. During the study period, eight enrolled patients presented with acute angle closure glaucoma after HD sessions.

The various causes of ESRD among the 87 participants in present study were recorded. Hypertension was found to be the most common cause (39.08%), followed by diabetes mellitus (21.84%) [Table/Fig-1].

Parameters	Frequency	Percentage
Diabetes mellitus	19	21.84
Hypertension	34	39.08
Diabetes mellitus+Hypertension	10	11.49
Other	24	27.59

[Table/Fig-1]: Various causes of ESRD in the study (n=87).
Other: glomerulonephritis, interstitial nephritis, pyelonephritis

The mean ACD decreased by 0.08 mm postdialysis, from 3.13±0.30 mm to 3.05±0.29 mm, and this decrease was found to be significant (p=0.0001). The mean LT increased by 0.06 mm postdialysis, from 4.04±0.42 mm to 4.10±0.42 mm, which was also found to be significant (p=0.0001). However, there was no significant change in CCT (from 495.13±15.56 SD to 495.08±15.52 SD) (p=0.533) [Table/Fig-2].

Parameters	Minimum (mm)	Maximum (mm)	Mean (mm)	SD	p-value
ACD Pre-HD	2.23	3.78	3.13	0.30	0.0001*
ACD Post-HD	2.20	3.70	3.05	0.29	
LT Pre-HD	2.64	4.83	4.04	0.42	0.0001*
LT Post-HD	2.69	4.88	4.10	0.42	
CCT Pre-HD	462	536	495.13	15.56	0.533
CCT Post-HD	463	535	495.08	15.52	

[Table/Fig-2]: Comparison of Anterior Chamber Depth (ACD), Lens Thickness (LT), and Central Corneal Thickness (CCT) before and after Haemodialysis (HD) (n=170).
ACD: Anterior chamber depth; LT: Lens thickness; CCT: Central corneal thickness; HD: Haemodialysis; mm: Milimetre; Test: paired t-test

The mean IOP increased by 0.18 mmHg post-HD, from 16.21±2.30 SD mmHg to 16.39±2.14 SD mmHg, but the difference was not significant (p=0.455) [Table/Fig-3].

Parameters	Minimum (mmHg)	Maximum (mmHg)	Mean (mmHg)	SD	p-value
IOP Pre-HD	11	22	16.21	2.30	0.4556
IOP Post-HD	12	20	16.39	2.14	

[Table/Fig-3]: Comparison of Intraocular Pressure (IOP) before and after Haemodialysis (HD) (n=170).
IOP: Intraocular pressure; HD: Haemodialysis. Test: paired t-test

DISCUSSION

It is a known fact that HD has detrimental systemic effects, such as thrombosis, infection, ischaemic steal syndrome, aneurysms, venous hypertension, haematoma, heart failure, prolonged bleeding, as well as metabolic and endocrine disorders like hypercalcaemia, metabolic acidosis, and electrolyte imbalance, all of which lead to a reduced quality of life. One of the reasons for morbidity in ESRD patients is the ocular side-effects of HD [7].

The present study was conducted on 170 eyes of 87 patients undergoing HD, with a mean age of 57.63±11.95 years. Out of these patients, 36 (41.38%) were females and 51 (58.62%) were males. Similar age range and sex distribution were reported in the studies by Caglayan M et al., and Dinc UA et al., [11,15]. The mean duration of dialysis in these patients was 2.88±1.76 years, ranging from 0.33 to 7 years. A study conducted by Gracitelli CPB et al., reported an average duration of HD treatment of 63±62 months (range 1-288 months) [12]. Another study by Chen H et al., reported a mean duration of HD of ±4.83 years [9].

In the current study, hypertension (39%) was found to be the most common cause of ESRD, followed by diabetes (21%). However, Caglayan M et al., reported diabetes mellitus as the predominant cause of ESRD (52%) [11]. In various studies, techniques for assessing anterior segment parameters have varied from ultrasound biomicroscopy and A-scan biometry to optical biometry [16-18]. Among these, optical biometry is considered the most accurate method, which was used in present study. The present study used Goldman's applanation tonometry which is considered a gold standard method for IOP measurement amongst ophthalmologists.

In present study, there was a significant increase in the mean LT by 0.06 mm postdialysis, from 4.06±0.42 SD mm to 4.12±0.42 SD mm (p=0.0001). Similarly, a study by Wang L et al., showed a significant rise in LT from 4.85±0.41 to 4.90±0.43 (p<0.05) [19]. However, a multimodal study conducted by Mayali H et al., did not observe a significant change in LT (from 4.56±0.38 to 4.53±0.39 mm) [17]. It has been postulated that there is an increase in urea trapping in the lens during HD, leading to an osmotic gradient between the lens and aqueous, causing fluid imbibition into the lens and temporary lens swelling [16,17].

The present study also found a statistically significant decrease in mean ACD by 0.08 mm postdialysis, from 3.13±0.30 mm to 3.05±0.29 mm (p=0.0001). A study by Chen H et al., showed a decrease in ACD from 2.642±0.073 mm to 2.613±0.077 mm after HD (p=0.006) [9]. Another study by Gracitelli CPB et al., reported a significant decrease in ACD (3.16±0.06, p=0.002) [12]. Wang F et al., found a statistically significant decrease in central ACD after HD in all groups, ranging from 2.87±0.31 to 2.84±0.26 mm in the wide-angle group, from 2.69±0.24 to 2.59±0.27 mm in the narrow-angle group, and from 2.65±0.15 to 2.59±0.16 mm in the extremely narrow-angle group [16]. However, Wang L et al., reported a slight decrease in ACD from 2.74±0.24 to 2.70±0.29, although it was not statistically significant (p>0.05) [19]. This decrease in ACD can be attributed to total body fluid loss and increased plasma COP after HD, causing fluid efflux from the extravascular to intravascular compartment [15]. As a result there is decrease in ocular perfusion pressure which can lead to decrease in aqueous production [18]. In addition, the increased thickness of the lens also contributes to a shallowing of ACD.

Throughout the years, the effect of HD on IOP has been a topic of debate over the years. The present study observed a mean increase in IOP of 0.18 mmHg after HD, from 16.21±2.30 mmHg to 16.39±2.14 mmHg, but the difference was not statistically significant (p=0.455). Additionally, no change in mean CCT was noted (p=0.533). Hojs R and Pahor D reported a decrease in mean IOP from 14.8±2.7 mmHg to 13.9±2.1 mmHg after HD, which was also not statistically significant [18]. Similarly, the study by Costagliola C and Mastropasqua L reported no change in IOP and corneal thickness post-HD [20]. According to these studies, modern HD techniques seem to eliminate the rapid changes in blood osmolality, blood pH, body weight, or systolic pressure, resulting in less frequent severe IOP elevation [18,20].

Since the initial report by Sitprija V and Holmes JH in 1964, significant rises in IOP after HD have been investigated [21]. An analysis of IOP changes conducted by Cecchin E et al., demonstrated a significant rise in IOP in 18% of their patients, with a mean increase of 1.2 mmHg during dialysis and 0.6 mmHg after the session, compared to a mean IOP of 14.9±1.4 mmHg before dialysis [10]. The study by Wang F et al., compared the IOP rise between patients with wide-angle glaucoma (from 18.7±3.8 to 19.7±5.4 mmHg), narrow-angle glaucoma (from 17.0±4.4 to 18.7±6.4 mmHg), and extremely narrow-angle glaucoma [16]. The IOP of the extremely narrow-angle group increased significantly after HD (from 17.0±4.7 to 18.4±3.8 mmHg) (p<0.05).

A study by Levy J et al., hypothesised that the increase in IOP during HD may be associated with a rapid reduction in plasma osmolality and a relative increase in urea concentration in the aqueous humour [22]. Removal of uraemic toxins and various solutes from the vascular compartment can lower serum osmolality [23]. During HD, an osmolar gradient is induced by the blood-aqueous barrier, which may lead to water movement into the aqueous humour and a subsequent increase in IOP [21].

A study by Kalayaci M et al., showed a significant mean decrease in IOP (p<0.001) from 12.2±3.5 to 10.8±2.2 mmHg, and mean CCT dropped from 502±41.2 to 494.1±35.4 μm (p<0.001) [24]. In a study by Dinc UA et al., mean IOP decreased from 14.7±3.1 to 13.4±2.4 mmHg after HD (p=0.005), and mean CCT also significantly decreased after HD, from 556.5±33.5 to 550.2±34.6 μm (p=0.002) [15].

Yang SJ et al., investigated changes in IOP after HD and reported that the mean IOP before HD was 15.1±2.6 mmHg, which decreased to 13.9±2.2 mmHg after HD [25]. The authors suggested that the probable cause of the decreased IOP is the hydrodynamic changes during HD and plasma COP alterations leading to fluid removal from the anterior chamber [26].

It is known that patients with chronic renal failure have insufficient local blood supply to the eyes, and fluctuations in IOP and shallowing of ACD caused by HD may worsen this condition or even result in severe irreversible ischaemic and hypoxic damage to the optic nerve and retina [16,19]. Although the increase in IOP observed in present study was not sufficient to cause acutely raised IOP, fluctuations in IOP may still affect blood supply to the eye. During the study period, eight enrolled patients developed acute Angle-closure glaucoma after HD sessions. In such cases, it would have been beneficial to consider preventive measures such as laser peripheral iridotomy before the HD session.

Limitation(s)

Limitations of the study include its cross-sectional design, which restricts the establishment of a long-term relationship between HD and ocular parameters. The single-point measurements do not capture dynamic variations in parameters over time, highlighting the need for further longitudinal studies to determine ophthalmic screening protocols in ESRD patients undergoing HD. The study did not consider changes in ACD based on the refractive status of the eye, which could have been a potential confounding factor. Gonioscopic evaluation of the angle structure was only performed in clinically narrow-angle patients and was not considered as part of the study. Lastly, the study's focus on anterior segment parameters may overlook potential changes in other ocular structures that could contribute to a more comprehensive understanding of the ocular effects of HD.

CONCLUSION(S)

The present comprehensive study assessing the effect of HD on anterior segment parameters of the eye in ESRD patients demonstrated a significant decrease in ACD and a significant increase in LT post-HD. Furthermore, no significant changes were observed in CCT and IOP before and after HD. These findings emphasise the importance of screening protocols for patients on dialysis and can assist in the prevention and early management of ocular complications such as acute congestive glaucoma.

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