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Pressure Changes in Patients with Chronic Renal Failure Undergoing Hemodialysis

Ana Dvalishvili[1], Tatsiana Imshenetskaya[2]

[1]New Vision University, Tbilisi, Georgia
[2]Belarusian Medical Academy of Post Graduate Education, Minsk, Belarus
Email: t.imshanetskaya@mail.ru

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Abstract

Purpose: To determine the effects of hemodialysis on intraocular pressure (IOP) and to evaluate the correlation of IOP changes with anterior chamber angle anatomy. **Patients and Methods:** The study included 80 eyes of 40 patients with chronic renal failure (CRF) undergoing hemodialysis at the High Technology Medical Center between October 2018 and October 2021. Hemodialysis (HD) was performed 3 times a week and the duration of the procedure was 3 - 5 hours. The enrolled patients were grouped according to the width of the anterior chamber angle. IOP was evaluated at three different times during HD. Intraocular pressure was measured in both eyes in an upright sitting position with iCare tonometer. **Results:** According to the study results, there was no statistically significant difference in the axial length between the three measurements ($p = 0.232$). In patients with normal anterior chamber depth, IOP decreased significantly (68.75%) or did not show any changes in their IOP during or after the session. In patients with moderate narrow-angle (22.5%), IOP revealed no statistically significant differences. In patients with narrow-angle (8.75%), there was a marked increase in IOP. Changes in intraocular pressure were correlated with the anatomy of the anterior chamber angle. Loss in body weight as a result of hemodialysis was statistically important ($p < 0.01$). **Conclusion:** A significant increase in mean was revealed during and after hemodialysis in patients with extremely narrow-angle in comparison to eyes with wide or moderately anterior chamber angle. Eyes with shallow anterior chambers are at risk of having impaired aqueous humor outflow facilities and, as a result, significantly increase IOP during HD. Because of the high prevalence of narrow angles in the Caucasian population, it is of clinical importance to investigate the IOP changes in patients on HD. The results of our study support the idea that iridocorneal angle anatomy is affecting IOP fluctuation occurring in patients with ESRD undergoing HD.

Keywords

Hemodialysis, Gonioscopy, Intraocular Pressure, Anterior Chamber Angle

1. Introduction

Chronic renal failure (CRF) is an irreversible and progressive process that results in end-stage renal disease (ESRD). Hemodialysis (HD) is an important and one of the commonest treatment options for ESRD [1] [2]. During HD, numerous metabolic parameters can change. These changes cause osmotic fluctuation in blood, vitreous and aqueous humor. Changes in IOP are one of the most common eye problems in patients undergoing HD [3].

Despite the technical advances, hemodialysis is far from ideal. Patients are exposed to potential systemic and ocular complications. Most common ocular complications associated with hemodialysis include changes in intraocular pressure (IOP) include the following: anterior ischemic optic neuropathy, uremic optic neuropathy, occipital lobe blindness, and endogenous endophthalmitis, dry eye, perilimbal and conjunctival calcium deposits, refractive changes, lenticular opacity and posterior subcapsular cataract formation, changes in retinal and choroidal thickness [4] [5] [6] [7].

The effect of HD to IOP changes during or after the procedure has been evaluated for almost more than 30 to 40 years. However, there is still no consensus on the matter, and various findings have been reported [2]-[8].

Published work about the changes in IOP during and after HD can be divided into three categories: reports showing an IOP rise, reports showing IOP decrease, and reports showing no change in IOP [1] [9]. Most of the previous results were limited either by a short follow-up period or a small number of patients.

Eyes with shallow anterior chambers are at risk of having impaired aqueous humor outflow facilities and, as a result, significantly increase IOP during HD. Because of the high prevalence of narrow angles in the Caucasian population, it is of clinical importance to investigate the IOP changes in patients on HD. Increased IOP is the main risk factor for the development of glaucoma. Also, the clinical importance of this study is caused by acute angle-closure Glaucoma attacks in patients with narrow anterior chamber angles undergoing HD. Acute angle-closure glaucoma is a sight-threatening condition; hence, the prevention of this condition is very important [2] [3] [9].

2. Materials and Methods

The study included 80 eyes of 40 patients (25 male and 15 female) with CRF undergoing hemodialysis at High Technology Medical Center between October 2018 and October 2021. HD was performed 3 times a week, and the duration of the procedure was 3 - 5 hours.

The enrolled patients were grouped according to the width of the anterior chamber angle. IOP was evaluated at three different times, measuring both eyes in an upright position with iCare tonometer. Also, blood pressure was measured before and after the session along with the body weight (See **Table 1**).

Moreover, each subject included in the study underwent a complete ophthalmologic evaluation in both eyes, including BCVA (Snellen chart) and refraction measurement, slit lamp examination, IOP measurement (using Goldmann applanation tonometry), dilated fundus examination, and gonioscopy.

IOP measurements were taken within 20 min before the procedure, during HD, and after hemodialysis.

Gonioscopy was performed in all patients after taking the initial IOP measurements.

Exclusion criteria include the following: history of ocular trauma; opacity of the cornea; any previous corneal surgery; current eye infections; total blindness; diagnosis of glaucoma; patients on antiglaucoma medication or with glaucoma surgery; proliferative diabetic retinopathy; ocular malignancy; retinal detachment; optic nerve abnormalities; baseline IOP greater than 22 mmHg; presence of glaucomatous optic disc changes, including excavation, thinning, or notching of the neuroretinal rim; and vitreous hemorrhage.

From the beginning, the total number of patients enrolled in the study was 145. Of these, 65 patients were excluded due to their ophthalmic medical history: proliferative DR, 22 patients; glaucoma, 11 patients; total blindness, 3 patients; current eye infection, 3 patients; corneal abnormality, 2 patients; eye surgery due to retinal detachment, 5 patients; optic disc abnormality other than glaucoma, 10 patients; macular abnormalities, 6 patients; vitreous hemorrhage, 3 patients.

Mean body weight before HD, 70.21 kg; range, 41 - 86 kg; and mean age was 51.65 ± 14.39 years (range 25 - 83 years). All 14 (35%) patients have a history of diabetes mellitus; 15 (37.5%) have a history of arterial hypertension; 11 (27.5%) have a history of renal disease (such as kidney stone, polycystic kidney diseas, glomerulonephritis, etc.) (See **Table 2**).

Table 1. Clinical characteristics of the study population.

Number of patients	40
Age (years)	51.65 ± 14.39 (25 - 83 years)
Male gender	25 (62.5%)
Female gender	15 (37.5%)
Systolic blood pressure before HD (mmHg)	153.2 ± 17.5
Systolic blood pressure after HD (mmHg)	142.5 ± 19.4
Diastolic blood pressure before HD (mmHg)	75.3 ± 10.4
Diastolic blood pressure after HD (mmHg)	72.5 ± 11.3
Mean body weight before HD	70.21 kg
Mean body weight after HD	69.25 kg

Table 2. Cause of hemodialysis.

Hypertensive nephropathy	15 (37.5%)
Diabetic nephropathy	14 (35%)
Ig A nephropathy	2 (2.5%)
Polycystic kidney disease	3 (7.5%)
Unknown	6 (15%)

Patients underwent 4-hour HD sessions 3 days per week. IOP was measured at 20 min before HD, during HD, and 30 min after the end-HD. On the other hand, IOP measurement was performed using an iCare tonometer (iCare, Helsinki, Finland).

Furthermore, the enrolled patients were grouped according to the width and degree of pigmentation of the angle of the anterior chamber. For the evaluation of the anterior chamber angle, gonioscopy was used.

The ACAs of each quadrant were evaluated by gonioscopy classified by the Shaffer grading system, which means numeric grades of the ACA. The widest open angle, grade 3 - 4; moderate narrow-angle, grade 2; extremely narrow angle, grade 1; and a closed angle is grade 0 [10] [11] [12].

It should be noted that Shaffer's grading system is based on the angle between the iris and the trabecular meshwork. In practice, the angle is graded according to the visibility of various angle structures. The system assigns a numerical grade (4 - 0) to each angle with associated anatomical description, angle width in degrees, and implied clinical interpretation.

Grade 4 (35˚ - 45˚) is the widest-angle characteristic of myopia and aphakia in which the ciliary body can be visualized with ease; it is incapable of closure. Grade 3 (25˚ - 35˚) is an open angle in which at least the scleral spur can be identified; it is also incapable of closure. Grade 2 (20˚) is a moderately narrow angle in which only the trabecular can be identified; angle closure is possible but unlikely. Grade 1 (10˚) is a very narrow angle in which only Schwalbe's line, and perhaps also the top of the trabecula, can be identified; angle closure is not inevitable, but the risk is high.

The features of gonioscopy require patients to be divided into three different groups: Group A patients with the widest open angle (grade 3 - 4), group B patients with moderate narrow angle (grade 2), and group C patients with very narrow angle (grade 1) (See **Table 3**).

In group A, we found 55 eyes with open anterior chamber angles (68.75%). In group B, 18 eyes were found with moderate narrow angle (22.5%). And in group C, 7 eyes were found to have very narrow angle (8.75%).

In patients with moderate or narrow angles, more accurate angle determination by anterior optical coherence tomography was done.

3. Results

Loss of body weight due to HD was statistically significant both in females and males ($p < 0.01$).

Table 3. Anterior chamber angle anatomy.

Group A: Grade 4 (35˚ - 45˚) is the widest angle and grade 3 is an open angle (25˚ - 35˚)	55 eyes (68.75%)
Group B: Grade 2 (20˚) is a moderately narrow angle	18 eyes (22.5%)
Group C: Grade 1 (10˚) is a very narrow angle	7 eyes (8.75%)

IOP readings were taken 20 min before HD, during HD (2 h after the procedure was started), and within 25 min after HD.

In group A, 55 eyes (68.75%,) with normal anterior chamber depth IOP decreased significantly in 45 patients during and/or after dialysis. In this group, before HD, IOP was 15.9 mmHg ± 7.04 mmHg, with an average decrease of 1.2 mm Hg during dialysis and 1.6 mm Hg after the end of the session. The other 10 patients did not show any statistically significant changes in their IOP during or after HD (See **Table 4**).

In group A, the mean increase in IOP after hemodialysis (0.35 mmHg) was not statistically significant; after ultrafiltration, however, the mean IOP showed a significant decrease of 1.48 mmHg.

Group B, consisting of 18 eyes (22.5%), with moderate narrow angle in 10 patients, IOP revealed no statistically significant differences.

In the other 8 patients, there was a moderate IOP increase: 16.05 ± 7.04 mmHg before HD, 17.05 ± 7.07 mmHg during HD, and 17.09 ± 7.07 mmHg after HD.

In this group, 2 patients developed acute-angle-closure glaucoma attack during the session of HD.

On the other hand, group C patients have 7 extremely narrow-angle eyes (8.75%). In this group, eyes were marked with an increased IOP after HD. Before HD, IOP = 18 mmHg ± 7 mmHg; during HD, IOP = 21 mmHg ± 9 mmHg; after HD, IOP = 21 mmHg ± 8 mmHg. Consequently, 3 patients developed acute angle closure glaucoma attack.

A significant increase in mean IOP during and after hemodialysis in group C (extremely narrow angle), in comparison to eyes with wide or moderately anterior chamber angle, revealed a statistically significant correlation between the changes in IOP during and after HD and the anterior chamber angle anatomy.

During HD sessions in group B, 2 patients, and group C, 3 patients developed complications such as nausea, headache, and vomiting; in some cases, these symptoms were observed in association with the rise in IOP. These patients were diagnosed with acute angle-closure glaucoma attack.

The mechanism that caused the decrease of IOP during hemodialysis in group A is still controversial. In group C, it has been reported that during HD, there is an increase in aqueous humor formation [13]. According to our findings, this does not induce a significant change in IOP in patients with a normal width of the anterior chamber depth, together with normal outflow capacity. However, in group C, with outflow obstruction, the rise of IOP is becoming significant. This study is showing that the possibility of an obstruction of aqueous humor outflow

Table 4. IOP changes before and after hemodialysis.

Shaffer s grading	Before HD	After HD
Grade 4 and Grade 3	15.09 mmHg ± 7.04 mmHg	14.05 mmHg ± 5.04 mmHg
Grade 2	16.05 mmHg ± 7.04 mmHg	17.05 mmHg ± 7.07 mmHg
Grade 1	18 mmHg ± 7 mmHg	21 mmHg ± 9 mmHg

should be kept in mind in patients with a significant narrowed anterior chamber depth.

Accordingly, systolic and diastolic blood pressure decreased statistically in all three groups ($p = 0.05$).

4. Discussion

The relationship between HD and IOP changes has been studied for almost 40 years; but reported findings, theories, and conclusions have shown very diverse results, and various hypotheses have been reported to illustrate this variability.

All reported work can be divided into three main categories: reports showing IOP decrease during HD, reports showing IOP rise after or during HD, and reports showing no change in IOP.

In 1964, Sitprija *et al.* studied the effect of HD on changes in IOP [1]. According to the authors, a mean rise in IOP was 5.9 mmHg within 3 h in patients who were undergoing HD. In 1966, Green and Watson reported a mean increase of 8.1 mmHg in 11 patients during HD [1] [14].

Gafter *et al.* reported an IOP increase after HD in 3 of the 30 patients. In the other 27 patients, IOP changes were not statistically significant [15].

Burn observed an IOP rise in one-third of the patients undergoing long-term HD [16]. Cecchin *et al.* found an IOP increase in 18% of patients during HD [17]. Tawara observed a significant increase of IOP in 5 eyes with compromised aqueous outflow facility; whereas in 8 eyes with normal aqueous outflow facility, IOP did not change significantly [6]. Leiba *et al.* reported a nonsignificant rise of IOP of 0.35 mmHg when measured after HD, and a significant drop of 1.48 mmHg for ultrafiltration. Tovbin *et al.* reported an IOP increase in 7 of the 19 patients [18].

Ramsell *et al.* observed that IOP did not increase continuously despite a steady decrease in osmolality; according to the authors, IOP fell during the first 2 h, rose during the second and third hours, and then remained constant from the third hour onward [3]. Hojs and Pahor did not find statistically significant differences in IOP before and after HD [19]. Rever *et al.* observed that IOP did not change following a 4-h HD session [20]. Pelit *et al.* did not show statistically significant differences between IOP before and after HD [21].

Costagliola *et al.* observed a significant decrease in IOP after HD. Tokuyama *et al.* reported statistically significant IOP changes (decreased of 1.8 mmHg) after HD [22].

Gutmann and Vaziri compared IOP values obtained in dialysis patients and compared them with a normal control group. IOP values were significantly lower in HD patients. An insignificant decrease in IOP was noted during the first 2 h of dialysis. This was followed by a slight rise above the baseline by the end of the dialysis [23].

The rise of IOP was explained by different theories: Some authors reported correlation between IOP and serum osmolarity, a rapid change of gradient between ocular compartments and plasma, and a shift of extracellular fluid from blood to the anterior chamber.

The proposed mechanism of IOP changes during dialysis is a disequilibrium between blood and aqueous osmolarity: During HD, osmotically active substances are removed by diffusion. As a result, there is a decrease in serum osmolality and loss of body fluids. Rapid reduction in plasma osmolality caused disequilibrium between the plasma and intraocular fluid and the unchanged ocular osmolality during HD. The relatively high urea concentration in the intraocular fluid during HD might cause fluid shifting from blood plasma to the anterior chamber.

In eyes with impaired aqueous outflow facilities, an increase of IOP is more prominent [17]. Narrow anterior chamber depth during HD further compromises outflow facilities [23] Therefore, a detailed ophthalmic examination should be done in patients who are receiving dialysis to detect high-risk individuals who can potentially develop ACG.

These findings are confirmed by Tawara *et al.* who reported that eyes with obstructed aqueous outflow pathways (including primary angle closure, peripheral anterior synechiae, angle neovascularisation, and ghost cell glaucoma) may develop IOP elevation due to a defective compensatory mechanism of aqueous humor drainage [5].

Because IOP elevation usually occurs during dialysis, and patients receiving dialysis have an increased risk of developing angle-closure glaucoma, preventive measures during dialysis should be taken with high-risk patients to avoid irreversible vision loss [8].

Additionally, fluid removal during ultrafiltration without concomitant albumin removal increases colloid osmotic pressure, leading to a fluid shift from the aqueous humor to the plasma and a decrease in IOP. According to Doshiro *et al.*, IOP changes were negatively associated with colloid osmotic pressure changes. [24] Tokuyama *et al.* described a correlation between colloid osmotic pressure and IOP changes, but according to the authors, there was no correlation with plasma osmolarity [13].

Our study found that the anatomy of the anterior chamber angle may be an important factor in explaining the change in IOP associated with HD. Our results showed a significant decrease in IOP in patients with open and widely open anterior chamber angle and increase in IOP in patients with narrow anterior chamber angle.

In order to account for changes in the anterior chamber angle, consideration of IOP and aqueous humor is essential.

Aqueous humor outflow facility and relationship with intraocular pressure changes were studied only in a few works.

According to Costagliola *et al.*, no statistically important difference was found between outflow facility and IOP changes during or after HD [22]. The work of Tawara *et al.* described that mean IOP increased significantly after 90 min in the eyes with severely decreased aqueous outflow facility and in the eyes with normal aqueous outflow facility; moreover, the mean percent change in IOP showed no significant difference at any time during HD [5] [6].

To summarize, different works have examined the influence and relationship of HD on changes in IOP; however, there are only opposite findings even in recent studies [3].

The possibility of the rise of acute IOP during HD is much more frequent than in normal patients. So in these patients, a more strict ophthalmic examination is needed [18].

Acute primary angle closure (APAC) is a medical emergency and remains a therapeutic challenge, particularly in ESRD patients [19].

To avoid severe IOP changes during HD in patients with moderate and extremely narrow anterior chamber angle prophylactic laser periphery iridotomy (LPI) may be done to prevent the development of acute-angle-closure glaucoma.

Regular ophthalmic examinations may be useful in patients undergoing HD with a diagnosis of glaucoma or narrow anterior chamber angle to avoid vision loss.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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