

CHANGES IN CHOROIDAL THICKNESS IN AND OUTSIDE THE MACULA AFTER HEMODIALYSIS IN PATIENTS WITH END-STAGE RENAL DISEASE

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Purpose: To evaluate changes in choroidal thickness in and outside the macula as a result of hemodialysis (HD) in patients with end-stage renal disease.

Methods: Patients with end-stage renal disease treated with maintenance HD in the Dialysis Unit of Sanggye Paik Hospital, Seoul, South Korea, were included in this study. The choroidal thickness was measured in and outside the macula before and after HD (paired *t*-test). Choroidal thickness in the macula was measured at the foveal center and 1.5 mm temporal to the foveal center and outside the macula was measured at superior, inferior, and nasal area 3.5 mm from the optic disk margin. Peripapillary retinal nerve fiber layer thickness, intraocular pressure, central corneal thickness, and systemic parameters such as serum osmolarity and blood pressure (BP) were measured before and after HD (paired *t*-test). We divided patients into two groups, diabetic and nondiabetic groups to compare the changes in choroidal thickness. Patients with diabetes were subdivided into two groups: severe retinal change group and moderate retinal change group (Mann–Whitney test). Pearson’s correlation test was used to evaluate the correlations between choroidal thickness and changes in serum osmolarity, BP, and body weight loss. Choroidal thickness and peripapillary retinal nerve fiber layer thickness were measured using spectral-domain optical coherence tomography.

Results: Fifty-four eyes of 31 patients with end-stage renal disease were included. After HD, the mean intraocular pressure was significantly decreased from 14.8 ± 2.5 mmHg to 13.0 ± 2.6 mmHg ($P < 0.001$). Choroidal thickness was reduced in all areas ($P < 0.001$). The reduction in choroidal thickness correlated with body weight loss, decrease in serum osmolarity, and decrease in systolic BP ($P < 0.05$). In the diabetic group, the mean choroidal thickness changes were greater than those in the nondiabetic group ($P < 0.05$). The severe retinal change group showed greater changes in choroidal thickness in all areas ($P < 0.05$). Other factors that significantly decreased after HD included serum osmolarity, body weight, and systolic BP (all $P < 0.001$). The diabetic group showed greater changes in serum osmolarity and body weight ($P < 0.001$, $P = 0.048$, respectively). The measured overall changes in peripapillary retinal nerve fiber layer thickness or central corneal thickness were not statistically significant.

Conclusion: Changes in body weight, serum osmolarity, and BP during HD may affect choroidal thickness in and outside the macula.

RETINA 37:896–905, 2017

Patients who are treated with maintenance hemodialysis (HD) due to end-stage renal disease (ESRD) have a higher incidence of ophthalmologic pathologies, such as diabetic retinopathy, exudative retinal detachment, and cataract.¹ In addition, many ocular problems including dysfunctional tear syndrome, conjunctival calcium deposits, and changes in refractive error, intraocular pressure (IOP) and central corneal thickness

(CCT) are frequently observed in patients with ESRD undergoing HD.^{2–7}

During HD, numerous metabolic parameters are changed, including blood urea nitrogen, sodium, chloride, potassium, and albumin by diffusion, resulting in a loss of body fluids and a decrease in serum osmolarity.⁸ This can affect the IOP, CCT, and some ocular parameters measured by optical coherence

tomography (OCT), including central foveal thickness, macular volume, retinal nerve fiber layer (RNFL) thickness, and choroidal thickness.⁹

The choroid plays an important role in the physiology of healthy eyes; a structurally and functionally normal choroidal vasculature is essential for retinal function. The choroid is responsible for supplying oxygen and nutrients to the retinal pigment epithelium (RPE) and the retina up to the inner nuclear layer. Choroidal vessels are poorly autoregulated and changes in perfusion directly alter the blood flow. Thus, abnormal choroidal blood volume or compromised blood flow may cause photoreceptor dysfunction and death.^{10–12}

Indocyanine angiography and laser Doppler flowmetry techniques provide information about the choroidal circulation but do not yield cross-sectional images.^{13,14} A noninvasive and objective cross-sectional imaging technique, OCT has been widely used in the diagnosis and follow-up of various macular disease, retinal vascular diseases, glaucoma, and even corneal diseases. However, adequate visualization of the choroid using OCT has not been possible until recently, owing to its posterior location, the presence of pigment in the RPE that attenuates the incident light and the dense vascular structure of the choroid.¹⁵

Recent studies have reported successful examination and measurement of choroidal thickness in normal and pathologic states by enhanced depth imaging OCT using the Heidelberg Spectralis (Heidelberg Engineering, Heidelberg, Germany).^{16–23} As a result, measurements of choroidal thickness changes with specific pathologies are becoming more common. Recently, some studies described changes in ocular parameters in patients with ESRD treated with HD. Yang et al²⁴ reported that there was a significant decrease in the IOP and subfoveal choroidal thickness after HD but no change in the thickness of the RNFL. Ulas et al²⁵ reported that there was a significant decrease in the subfoveal, temporal, and nasal (apart from the fovea) choroidal thickness and IOP, but no change in the retinal thickness or the CCT.

However, the majority of the studies showed changes in choroidal thickness just below the fovea; a small number of the studies reported nasal and temporal (around the fovea) choroidal thickness.

During HD, changes in hemodynamic states may affect choroidal thickness by means of fluid redistribution and changing of plasma colloid osmotic pressure across the walls of the vessels. Because the blood supply of the eye is derived from the ophthalmic artery, one entering the uvea nasally and one temporally along the horizontal meridian of the eye near the optic nerve, measurement of choroidal thickness centering the optic disk may be more meaningful.²⁶

Recently, Oh et al²⁷ reported that the measurement of choroidal thickness on peripapillary circle scan images for RNFL analysis was highly reliable and efficient. To the best of our knowledge, there have been no published studies that measured choroidal thickness in and outside the macula in patients with ESRD being treated with HD.

Therefore, the present study was designed to evaluate the changes in RNFL thickness, IOP, and choroidal thickness in and outside the macula in patients with ESRD being treated with HD.

Methods

The present study was a cross-sectional study conducted in the Department of Ophthalmology of Sanggye Paik Hospital from April 2015 to September 2015. The institutional review board at Inje University approved our study protocol. This study was performed in adherence with the tenets of the Declaration of Helsinki. Informed consent was obtained from all study participants.

Patients with ESRD who were being treated with maintenance HD in the Dialysis Unit of Sanggye Paik Hospital, Seoul, South Korea, were recruited. The subjects received 3.5-hour to 4-hour hemodialysis sessions 3 times per week, with an ultrafiltration volume >2,000 mL due to high interdialytic weight gain. They underwent HD with high-performance dialysers at a blood flow rate of 250 mL/minute and under strict blood pressure (BP) and dry weight control.

The inclusion criteria were patients with eyes having axial length (AL) 22.1 mm to 25.9 mm and no history of glaucoma, uveitis, choroidal neovascularization, or other macular diseases such as epiretinal membrane, macular hole, or macular edema.

The exclusion criteria were the presence of media opacity that would prevent the examination of the retina and OCT imaging, and a history of laser treatment or vitrectomy surgery.

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None of the authors have any financial/conflicting interests to disclose.

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All participants were evaluated at the midweek hemodialysis session.

Blood pressure, body weight, serum osmolarity, albumin, blood urea nitrogen, creatinine, and electrolytes were measured 15 minutes before and 15 minutes after a hemodialysis session.

A detailed ophthalmologic examination including visual acuity, IOP, CCT, AL, anterior segment and fundus examination, and measurement of the peripapillary RNFL and choroidal thicknesses 30 minutes before and 30 minutes after HD was performed.

The IOP was measured using Goldmann applanation tonometry, CCT, and AL were measured using an AL-scan optical biometer (Nidek Co, Ltd, Gamagori, Japan).

The peripapillary RNFL and choroidal thicknesses were measured with the Spectralis OCT (Heidelberg Engineering). All OCT scans were acquired by the same operator using enhanced depth imaging mode with an eye-tracking system (Automatic Real Time system), and the same sites were scanned before and after HD.

Peripapillary RNFL thickness was measured using the automatic segmentation values of the Spectralis

OCT. The peripapillary RNFL thickness was analyzed in six areas: superotemporal, superonasal, inferotemporal, inferonasal, temporal, and nasal.

Vertical and horizontal scans were taken through the fovea for subfoveal choroidal thickness measurements.

The choroidal thickness was measured in and outside the macula. The choroidal thickness in the macula was measured at the foveal center and 1.5 mm temporal to the foveal center. Choroidal thickness outside the macula was measured in the superior, inferior, and nasal areas 3.5 mm from the optic disk margin (Figure 1). The choroidal thickness was measured from the outer portion of the hyperreflective line corresponding to the RPE to the chorioscleral junction that was defined as a hyperreflective line between the large vessel layer of the choroid and the sclera.

Because patients with diabetes may have vascular changes related to the disease, we divided participants into diabetic and nondiabetic groups. The grade of diabetic changes in the retina may influence the role of choroidal vessels by histologic changes. We subdivided the diabetic group into two groups: severe

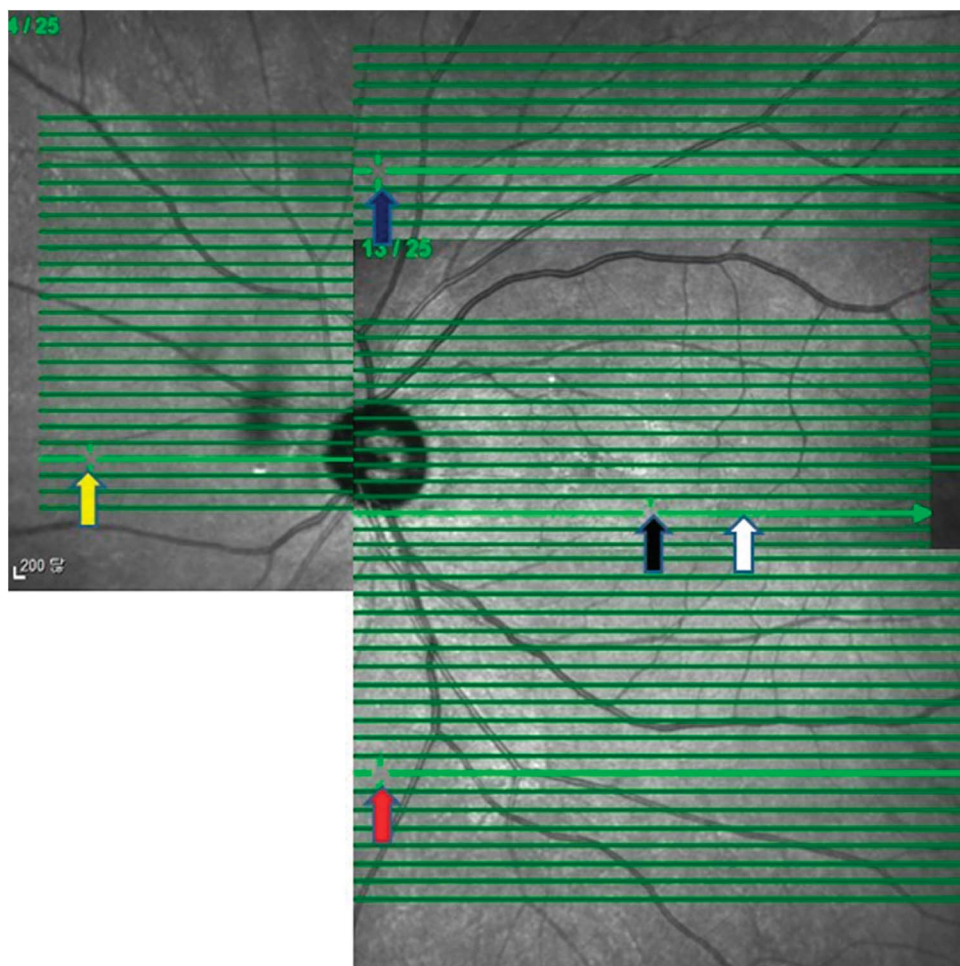


Fig. 1. Measurement of choroidal thickness. Choroidal thickness of the macula was measured at the foveal center (black arrow) and 1.5 mm temporal to the foveal center (white arrow). Choroidal thickness outside the macula was measured at the superior (blue arrow), inferior (red arrow), and nasal (yellow arrow) areas 3.5 mm apart from the optic disk margin.

retinal change group and moderate retinal change group. The severe retinal change group included patients with severe or very severe nonproliferative diabetic retinopathy or untreated proliferative diabetic retinopathy. The moderate retinal change group included patients with mild or moderate nonproliferative diabetic retinopathy.

The data were analyzed using the SAS (Statistical Analysis Software) version 5.1. The paired *t*-test was used to compare IOP, CCT, peripapillary RNFL thickness, and choroidal thickness before and after HD. Pearson's correlation test was used to evaluate the correlations between choroidal thickness and body weight loss, changes in serum osmolarity and systolic BP (SBP) during HD. Multiple linear regression analysis was performed to obtain which parameters are most closely associated with change in choroidal thickness. The nonpaired *t*-test was used to check comparison between diabetic and nondiabetic groups. It is also used to check comparison between severe retinal change and moderate retinal change groups. We also conducted one-way analysis of variance to compare a difference in changing choroidal thickness among five areas.

A *P*-value <0.05 was accepted as statistically significant.

Results

Fifty-four eyes of 31 patients (16 men and 15 women; 19 patients with diabetes, 12 patients without diabetes; age, 35–70 years, mean age, 60.1 ± 7.8 years) were included in this study. Twenty-nine eyes were pseudophakic, and 25 eyes were phakic eyes. The mean duration of HD was 52.1 ± 29.1 months. The cause of ESRD included diabetic nephropathy ($n = 19$), hypertensive nephrosclerosis ($n = 6$), immunoglobulin A nephropathy ($n = 3$), and chronic glomerulonephritis ($n = 3$). The baseline characteristics of the patients are summarized in the Table 1.

The mean body weight decreased from 65.7 ± 13.0 kg to 63.4 ± 12.6 kg after HD. The mean SBP decreased from 144.1 ± 22.5 mmHg to 129.6 ± 21.1 mmHg, and the mean arterial pressure decreased from 100.1 ± 14.7 mmHg to 92.8 ± 15.6 mmHg after HD. The mean changes in body weight, SBP, and mean arterial pressure were 2.3 ± 0.9 kg, 14.5 ± 20.4 mmHg, and 7.2 ± 14.2 mmHg, respectively. The changes in systemic parameters of the patients are listed in Table 2.

The mean IOP decreased from 14.8 ± 2.5 mmHg to 13.0 ± 2.6 mmHg after HD. The decline in IOP was statistically significant (paired *t*-test, $P < 0.001$), but combine observations about IOP

Table 1. Baseline Characteristics of the Participants

	All Participants (n = 31)	Range
Age, years	60.1 ± 7.8	35–70
Gender (male/female)	16/15	
Duration of HD, months	59.1 ± 29.1	11–120
Height, cm	163.2 ± 9.0	145–180.6
Weight, kg	65.7 ± 13.0	42.1–92.1
Body mass index, kg/m ²	24.1 ± 2.5	18.4–28.0
AL, mm	23.9 ± 1.1	22.1–24.8

correlations with body weight, serum osmolarity, and SBP into a single statement that there was no association observed.

The mean ocular perfusion pressure decreased from 56.6 ± 10.2 mmHg to 52.9 ± 10.3 mmHg. The decline in mean ocular perfusion pressure was statistically significant (paired *t*-test, $P = 0.041$). During HD, changes in the CCT and peripapillary RNFL thickness, including the superotemporal, superonasal, inferotemporal, inferonasal, temporal, and nasal areas were not statistically significant (Table 3).

The changes in choroidal thickness at the macula and outside the macula were statistically significant after HD (Figure 2, Table 3). Combine observations about choroidal thickness correlations with body weight loss, serum osmolarity, and SBP into a single statement that there was statistically significant association observed (Table 4). Multiple regression linear analysis that included changes in body weight, serum osmolarity, and SBP showed that changes in choroidal thickness were correlated with changes in body weight ($P = 0.007$), SBP ($P = 0.048$), and serum osmolarity ($P < 0.001$) (changes in choroidal thickness [μm] = $-1.779 + 0.296 \times$ changes in body weight + $0.055 \times$ changes in SBP + $0.420 \times$ changes in serum osmolarity) (Figures 3, 4).

Analysis of variance with Bonferroni correction revealed that the superior area showed smaller changes in choroidal thickness than the inferior area ($P = 0.047$), but the difference among the other areas were not statistically significant ($P > 0.05$).

In this study, we divided the participants into 2 groups; 30 eyes were included in the diabetic group and 24 eyes in the nondiabetic group. Changes in serum osmolarity and body weight were greater in the diabetic group (nonpaired *t*-test, $P < 0.001$, $P = 0.048$, respectively).

The mean change in choroidal thickness in the macular area, which was measured at the foveal center and 1.5 mm temporal to the foveal center, was greater in the diabetic group (22.8, 18.8 μm) than in the

Table 2. The Effect of HD on Body Weight, BP, Serum Osmolarity, Electrolytes, Albumin, Blood Urea Nitrogen, and Creatinine

	Before HD	After HD	<i>P</i> *
Body weight, kg	65.7 ± 13.0	63.4 ± 12.6	<0.001†
SBP, mmHg	144.1 ± 22.5	129.6 ± 21.1	<0.001†
DBP, mmHg	78.1 ± 13.9	74.5 ± 16.6	0.184
MAP, mmHg	100.1 ± 14.7	92.8 ± 15.6	0.008†
Serum osmolarity, mOsm/L	317.5 ± 12.0	294.4 ± 11.7	<0.001†
Serum sodium, mEq/L	135.9 ± 3.2	136.8 ± 1.8	0.023†
Serum potassium, mEq/L	5.1 ± 0.7	3.7 ± 0.5	<0.001†
Serum chloride, mEq/L	99.3 ± 4.2	97.4 ± 2.3	0.001†
Serum albumin, g/dL	3.9 ± 0.3	4.4 ± 0.5	<0.001†
Serum BUN, mg/dL	62.8 ± 14.9	21.4 ± 7.2	<0.001†
Serum creatinine, mg/dL	9.3 ± 4.0	3.8 ± 1.9	<0.001†

*Paired *t*-test.

†Statistically significant difference before and after HD.

BUN, blood nitrogen urea; DBP, diastolic BP; MAP, mean arterial pressure.

nondiabetic group (15.1, 10.3 μ m) (nonpaired *t*-test, *P* = 0.006, *P* < 0.001, respectively) (Table 5). The mean change in choroidal thickness outside the macula in the diabetic group (15.9, 18.9, and 17.4 μ m) was also significantly different from that in the nondiabetic group (11.2, 12.1, and 12.3 μ m) (nonpaired *t*-test, *P* = 0.026, *P* < 0.001, *P* = 0.005, respectively) (Table 5). However, the change in IOP was not significantly different between the 2 groups.

We furthermore subdivided the diabetic group into two groups: severe retinal change group and moderate retinal change group. Twenty-four eyes were included in the severe retinal change group, and 6 eyes were in the moderate retinal change group.

Severe retinal change group showed greater changes in choroidal thickness in all areas (Table 6).

Discussion

Until recently, it was difficult to image the full thickness of the choroid because the RPE and the dense vascular structure of the choroid impede visualization. Decreased signal strength posterior to the RPE is compensated by the image enhancement software, which enables visualization of the margin where the choroidal tissue meets the sclera and allows choroidal thickness measurements to be performed.¹⁵

Table 3. Changes in IOP, CCT, Peripapillary RNFL Thickness, and Choroidal Thickness (CT) After HD

	Before HD	After HD	<i>P</i> *
IOP, mmHg	14.8 ± 2.5	13.0 ± 2.6	<0.001†
MOPP, mmHg	56.6 ± 10.2	52.9 ± 10.3	0.041†
CCT, μ m	551.0 ± 29.4	548.9 ± 30.4	0.103
Peripapillary RNFL, μ m			
Superotemporal	131.2 ± 20.0	131.9 ± 20.6	0.161
Superonasal	112.2 ± 14.3	113.5 ± 14.7	0.070
Inferotemporal	140.5 ± 19.3	141.0 ± 19.4	0.247
Inferonasal	102.7 ± 16.3	103.0 ± 17.3	0.747
Temporal	78.0 ± 8.5	79.0 ± 9.6	0.071
Nasal	70.6 ± 14.0	71.2 ± 13.8	0.149
Choroidal thickness, μ m			
In the macula			
Foveal center	233.6 ± 45.2	214.2 ± 43.8	<0.001†
1.5 mm temporal to the foveal center	211.1 ± 42.7	196.1 ± 41.0	<0.001†
Outside the macula			
Superior area	207.3 ± 15.3	193.4 ± 15.7	<0.001†
Inferior area	173.2 ± 31.5	157.9 ± 29.1	<0.001†
Nasal area	181.3 ± 48.1	166.1 ± 46.9	<0.001†

*Paired *t*-test.

†Statistically significant difference before and after HD.

Inferior area, 3.5 mm inferior to the optic disk; MOPP, mean ocular perfusion pressure; Nasal area, area located at 3.5 mm nasally from the optic disk; Superior area, 3.5 mm superior to the optic disk.

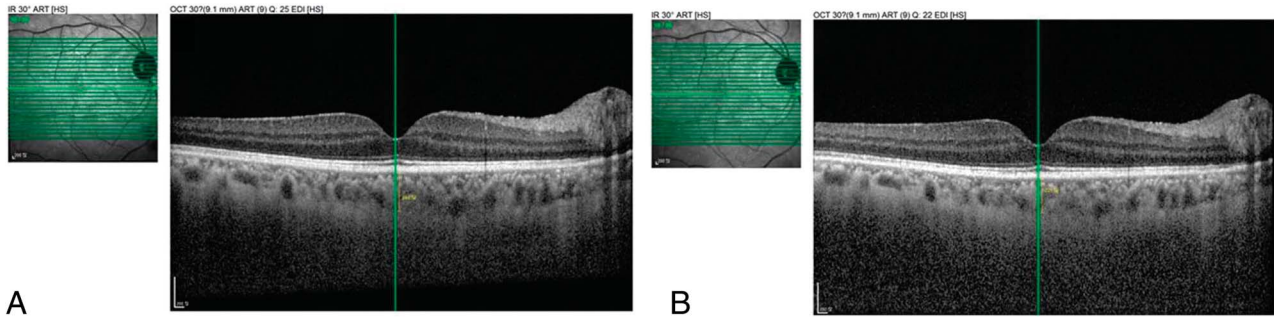


Fig. 2. Representative examples of enhanced depth imaging (EDI) OCT showing changes in the choroidal thickness before and after HD. The subfoveal choroidal thickness decreased from 248 μm (before HD, **A**) to 221 μm (after HD, **B**). IR, infrared; ART, automatic real time; HS, high speed.

In addition to imaging, eye tracking ensures that all of the images to be averaged are taken from the same retinal location and provides high-resolution cross-sectional information.²⁸ As a result of the advances in imaging modalities, understanding of the choroid is increasing, and choroidal changes in various disease states are receiving growing attention.

There are many ocular conditions that may affect the choroid. Wei et al²⁹ showed that the eyes with longer AL have a thinner choroid. To exclude this variation, we included patients with eyes having AL 22.1 mm to 25.9 mm. Some authors have reported that patients with age-related macular degeneration, glaucoma, or diabetic retinopathy have thinner choroids,³⁰ whereas those with chronic central serous chorioretinopathy or Vogt–Koyanagi–Harada disease have thicker choroids.¹⁷

In addition, various systemic states may affect the choroid. Ikuno et al³¹ showed that aging is a factor associated with changes in choroidal thickness; older patients are reported to have thinner choroids. Yilmaz et al³² have demonstrated that the body mass index may have an influence on the choroidal thickness of

healthy persons: individuals with high body mass index have thinner choroids than individuals with low body mass index. Tan et al³³ reported a significant diurnal variation in choroidal thickness, and Usui et al³⁴ reported that there was a correlation between diurnal systolic BP fluctuation and choroidal thickness fluctuation. To exclude this variation, we included only patients of second session (from 11 AM to 3 PM) HD.

Yang et al²⁴ demonstrated a decrease in subfoveal choroidal thickness, and Ulas et al²⁵ reported a decrease in subfoveal, temporal, and nasal (around the fovea) choroidal thickness after HD. Because the blood supply of the eye is derived from the ophthalmic artery and it divides into two branches near the optic nerve, we have studied changes in choroidal thickness in and outside the macula (centering the optic disk) occurring after HD in patients with ESRD.²⁶

In this study, we found a significant decrease in choroidal thickness in all areas. Choroidal thickness decreased after HD, and the changes in serum osmolarity were significantly associated with this decrease. Furthermore, the reduction in choroidal

Table 4. Correlation Between the Changes in Serum Osmolarity, Weight Loss, SBP and the Changes in Choroidal Thickness

Area of Choroid	Changes in Serum Osmolarity		Weight Loss		Changes in SBP	
	Pearson's Correlation Coefficient	P*	Pearson's Correlation Coefficient	P*	Pearson's Correlation Coefficient	P*
In the macula, μm						
Foveal center	0.418	0.002†	0.385	0.004†	0.328	0.022†
1.5 mm temporal to foveal center	0.324	0.017†	0.304	0.023†	0.314	0.026†
Outside the macula, μm						
Superior area	0.325	0.017†	0.297	0.029†	0.390	0.005†
Inferior area	0.487	<0.001†	0.311	0.022†	0.283	0.037†
Nasal area	0.500	<0.001†	0.346	0.010†	0.336	0.013†

*Pearson's correlations.

†Statistically significant difference before and after HD.

Inferior area, 3.5 mm inferior to the optic disk; Nasal area, area located at 3.5 mm nasally from the optic disk; Superior area, 3.5 mm superior to the optic disk.

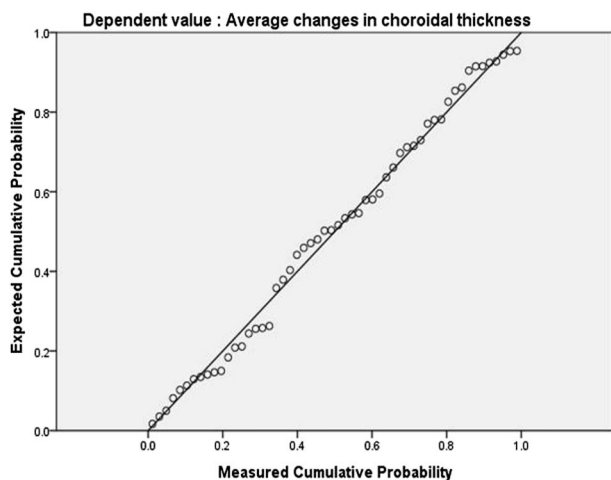


Fig. 3. Multiple regression linear analysis that included changes in body weight, serum osmolarity, and SBP showed that changes in choroidal thickness were correlated with changes in body weight ($P = 0.007$), SBP ($P = 0.048$), and serum osmolarity ($P < 0.001$) (changes in choroidal thickness [μm] = $-1.779 + 0.296 \times \text{changes in body weight} + 0.055 \times \text{changes in SBP} + 0.420 \times \text{changes in serum osmolarity}$).

thickness was correlated with a loss in body weight. Yang et al²⁴ also reported that the reduction in choroidal thickness correlated with body weight loss during a HD session.

Because HD corrects the excessive accumulation and abnormal distribution of body fluid, the systemic hemodynamic parameters, such as BP, body weight, and serum osmolarity change significantly after a single HD session.³⁵

During HD, ultrafiltration leads to a gradual reduction in the extracellular fluid compartment and eventually increases the oncotic pressure of the extracellular space, which in turn draws fluid out of the surrounding tissue to buffer the loss of extracellular fluid.^{25,36}

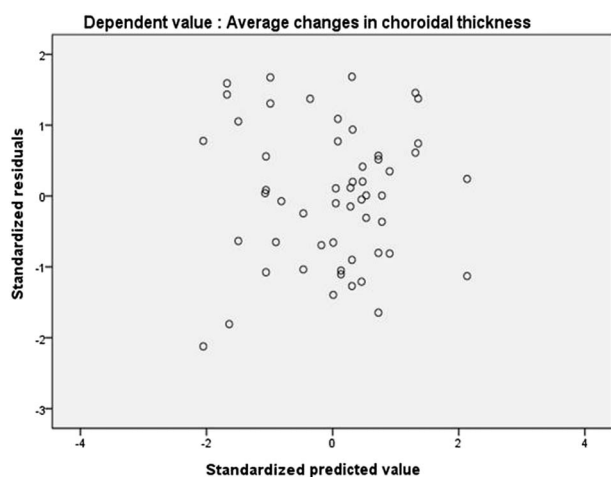


Fig. 4. Scatter plot showing the correlation between the expected changes in choroidal thickness and the measure changes in choroidal thickness by multiple regression linear analysis.

However, some authors described that there was a significant increase in choroidal thickness. This may result from the redistribution of fluid due to increased synthesis of large, osmotically active proteoglycans, which pull water into the choroid.^{37,38} We observed choroidal thinning after HD. Therefore, we suspected that ultrafiltration-induced hypovolemia and the increased plasma oncotic pressure may play a role in the changes in choroidal thickness.

In the present study, choroidal thickness decreased after HD and the changes in SBP were significantly associated with this decrease. Choroidal autonomic regulation could affect the choroidal thickness because of its composition or vascular nature. Tanabe et al³⁹ showed a significant correlation between the ratio of the vertical and horizontal diameters and the choroidal thickness. Vance et al⁴⁰ showed the effects of sildenafil citrate (phosphodiesterase-5 inhibitor) on the choroidal thickness by vasodilatory effect of nitric oxide. Dadaci et al⁴¹ compared the choroidal thickness measurements of healthy pregnant women obtained in the first trimester with measurements obtained in the third trimester. They reported a significant decrease in choroidal thickness in the period of the third trimester due to vasoconstriction related to the increased adrenoceptor activity and higher $\alpha 1$ -adrenoceptor concentration in this period. End-stage renal disease may be accompanied by reversible sympathetic activation and the stimulation of the renin-angiotensin system by ultrafiltration-induced hypovolemia during HD may cause intradialytic sympathetic activation.^{42,43} The changes in BP before and after HD are larger than the diurnal variation. Although the regulatory ability of patients with ESRD is deficient, the hemodynamic change during HD might be enough to cause significant response of the choroid.

The reduction in choroidal thickness was greater in patients with diabetes than in patients without diabetes. We speculate that this might be due to diabetes-related vascular changes in the choroid and greater reduction in serum osmolarity and body weight in patients with diabetes.

In addition, we subdivided the diabetic group into two groups: severe retinal change group and moderate retinal change group. We found a greater reduction in choroidal thickness in the severe retinal change group. This might be due to severe changes in retinal vasculature and an overall reduction in choroidal blood flow in the severe retinal change group. Some authors reported selective filling of the choriocapillaris during indocyanine green angiography and a decrease in choroidal blood flow during laser Doppler flowmetry in association with nonproliferative diabetic retinopathy. Such findings indicate that diabetic choroidopathy might

Table 5. Comparisons of Patients with Diabetes and Patients Without Diabetes

	Diabetes	Nondiabetes	P*
Age, years	58.2 ± 8.7	63.3 ± 5.1	0.077
Gender (male/female)	13/3	3/12	
Duration of HD, months	46.7 ± 27.2	60.8 ± 31.2	0.195
Weight loss, kg	2.5 ± 0.7	2.1 ± 0.6	0.048†
Decreased in SBP	16.33 ± 18.74	13.42 ± 21.80	0.206
Changes in serum osmolarity, mOsm/L	25.9 ± 3.9	18.8 ± 4.3	<0.001†
Decreases in choroidal thickness, μm			
In the macula			
Foveal center	22.8 ± 9.4	15.1 ± 9.9	0.006†
1.5 mm temporal to the foveal center	18.8 ± 7.4	10.3 ± 5.3	<0.001†
Outside the macula			
Superior area	15.9 ± 8.7	11.2 ± 6.0	0.026†
Inferior area	18.9 ± 4.7	12.1 ± 6.3	<0.001†
Nasal area	17.4 ± 7.5	12.3 ± 4.8	0.005†

*Nonpaired t-test.

†Statistically significant difference before and after HD.

Inferior area, 3.5 mm inferior to the optic disk; Nasal area, area located at 3.5 mm nasally from the optic disk; Superior area, 3.5 mm superior to the optic disk.

exist before the onset of diabetic retinopathy.^{44,45} We observed greater changes in choroidal thickness in the diabetic group, especially in the severe retinal change group. Diabetic choroidopathy may affect the autonomic compensatory function of the choroid.

Joseph et al⁴⁶ reported that there are broad range of choroidal thickness depending on the location in the eye, the macular choroidal thicknesses ranged from 157 μm to 272 μm, whereas the peripapillary choroidal thicknesses ranged from 149 μm to 229 μm. In addition, the choroid and the sclera are easily separated anteriorly, creating a potential space—the suprachoroidal or perichoroidal space—and the choroid is tightly adherent to the optic nerve. We measured the choroidal thickness 3.5 mm far from the optic disk margin and

might be and enable us to observe the changes in choroidal thickness greater than just around the optic disk.

Many conflicting results concerning the effects of HD on the IOP have been reported. Yoon et al⁴⁷ and Minguela et al⁴⁸ reported an increase in the IOP caused by HD. Hojs and Pahor³⁶ found no significant changes in IOP during HD, whereas Tokuyama et al⁴⁹ and Gutmann et al⁵⁰ reported a decrease in the IOP.

In our study, the mean IOP decreased significantly after HD, with a mean reduction of 1.8 ± 1.8 mmHg (P < 0.001). The CCT was not significantly changed before and after HD; we thought HD might lead to a reduction in IOP.

In the present study, the RNFL thickness was similar before and after HD. Previous studies by Ulas et al²⁵

Table 6. Comparisons of Changes in Choroidal Thickness Between Severe Retinal Change Group and Moderate Retinal Change Group of Patients with Diabetes

Decreases in Choroidal Thickness	Severe Retinal Change Group	Moderate Retinal Change Group	P*
In the macula, μm			
Foveal center	24.9 ± 9.0	16.3 ± 5.6	0.004†
1.5 mm temporal to the foveal center	21.5 ± 4.9	11.3 ± 6.3	0.002†
Outside the macula, μm			
Superior area	17.5 ± 8.5	11.5 ± 6.8	0.042†
Inferior area	18.9 ± 4.7	13.8 ± 3.8	0.021†
Nasal area	18.9 ± 7.6	11.7 ± 2.3	0.031†

*Mann-Whitney test.

†Statistically significant difference before and after HD.

Inferior area, 3.5 mm inferior to the optic disk; Nasal area, area located at 3.5 mm nasally from the optic disk; Superior area, 3.5 mm superior to the optic disk.

and Yang et al²⁴ also revealed no significant changes in RNFL thickness after HD. On the other hand, Kang et al⁵¹ reported a significant reduction in RNFL thickness during HD. To thoroughly explore the changes in RNFL thickness after HD, further studies with a larger number of patients should be performed.

Our study has some limitations. Firstly, the study sample was relatively small, and further research with a larger sample is required to draw definite conclusions about the changes in choroidal thickness and IOP. Secondly, we performed all the measurements 30 minutes before and 30 minutes after HD. Conducting more OCT examinations at time points when the body has had more time to achieve full equilibrium and fluid balance might have yielded different results.

Changes in body weight, serum osmolarity, and BP during HD may affect choroidal thickness in and outside the macula. Further studies are needed to evaluate the changes that may occur in various ocular pathological conditions after HD in patients with ESRD.

Key words: choroidal thickness, hemodialysis, intraocular pressure, spectral domain optical coherence tomography, serum osmolarity.

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