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Original Article

# Visual Acuity and Contrast Sensitivity Association Among Hemodialysis Patients

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ABSTRACT

Introduction: This study aimed to assess the association between visual acuity (VA) and contrast sensitivity (CS) in patients with end-stage renal disease (ESRD) undergoing hemodialysis (HD), stratified by diabetes mellitus (DM) status. Methods: A cross-sectional study with a total of 100 HD patients was enrolled. Based on their HbA1c levels, they were categorized as having DM or as normal. They received a thorough eye examination, and those with corneal disease, cataracts, and macular disease were excluded. Best-corrected VA (BCVA) was evaluated using the Early Treatment Diabetic Retinopathy Study (ETDRS) chart, and CS was assessed using the MARS numeral CS chart. Fisher's exact test was employed to compare VA and CS based on DM status. Results: We analyzed 100 patients (185 eyes), consisting of 51 (51%) males and 49 (49%) females. The mean age of the study group was 47±12.8 (15-76) years. The BCVA in DM and non-DM was mostly in the 0.50-0.00 LogMAR category. CS values in DM and non-DM were mostly in >1.52 LogCS category. VA and CS were significantly different in both DM and non-DM groups (p=0.03; p=0.00, respectively). A strong correlation between VA and CS was also observed in both groups (r=0.644; r=0.573, respectively). Conclusion: Visual acuity and CS in ESRD patients with DM undergoing HD had significant differences from those without DM. BCVA was strongly correlated with CS in both groups. Monitoring VA and CS in HD patients with DM provides early detection of vision-threatening changes, helps prevent severe visual impairment and improves patients' quality of life.

## Introduction

End-stage renal disease (ESRD) is the final stage of chronic renal failure, characterized by a decrease in the glomerular filtration rate below 15 mL/min (1). ESRD has become a serious global health problem with a prevalence of 10.5 million people and is expected to increase, with the most significant growth occurring in Asia. In Indonesia, ESRD cases have increased significantly from 15.3 thousand in 2012 to 23.8 thousand in 2017 (2). ESRD patients have permanent deterioration in renal function and, therefore, require renal replacement therapy to maintain body homeostasis. Approximately 98% of ESRD patients in Indonesia choose Hemodialysis (HD) therapy (2). HD aims to eliminate excess fluid and metabolic byproducts from the extracorporeal blood and to preserve the acid-base balance and electrolytes (3).

The ocular and renal systems are the targets of end-organ damage in various pathologies. This can occur simultaneously due to common disease processes, or specific renal conditions leading to secondarily ocular involvement. The kidney and retina develop during the same embryonic stage around the fourth to sixth week of gestation, thus sharing a strong correlation between eye and kidney diseases (4). Patients with ESRD are at an increased risk of ocular problems due to uraemia, effects of HD and other co-morbid conditions such as diabetes, hypertension and cardiovascular disease (5). Common ocular problems among patients on HD include cataract, retinal changes (retinopathy, retinal haemorrhage, vitreous haemorrhage and retinal detachment) and other conjunctival and corneal changes (5).

The consequences of ESRD on a patient's eyes are complicated and varied. Ocular manifestations found in ESRD patients include conjunctival calcium deposits, dry eye syndrome, intraocular pressure (IOP) fluctuation leading to glaucoma, cataract, and macular oedema (6,7). A population study in Singapore observed that the prevalence of visual loss was three times greater in patients with ESRD (8). Moreover, previous studies also found that ocular manifestations were more common in ESRD patients with DM. It could cause negative impacts on visual acuity (VA), contrast sensitivity (CS), colour vision, visual field, and depth perception (6,9). There are several studies discussing ocular manifestations in ESRD patients with DM, but a study about VA and CS in ESRD patients with DM specifically is still lacking. Thus, we performed this study on 100 ESRD patients who underwent HD, and analyzed the VA and CS function based on DM status.

## Method

### Study Design

This cross-sectional study was a part of Diabetic Ocular Renal Surabaya Study (DiORSS) Group and was conducted at the HD Unit, in Dr. Soetomo General Academic Hospital (DSGAH) in May-June 2019. All DM and non-DM patients with ESRD who underwent regular HD were enrolled in this study. Before subject recruitment, ethical clearance was obtained from the IRB and written informed consent was acquired from all the participants. All the procedures performed in this study were in accordance with the ethical standards of the institutional research committee and the Declaration of Helsinki.

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Inclusion criteria consisted of all DM and non-DM patients with ESRD who underwent regular HD in HD unit DSGAH and were willing to join the research. Demographic profiles and medical histories including age, gender, educational background, VA, CS, and DM status (DM or non-DM group) were collected. While exclusion criteria were participants with corneal disease, cataracts, active infection/inflammation, and age-related macular degeneration patients. After providing written informed consent, patients received a thorough ophthalmology examination including BCVA assessment, anterior segment examination using slit-lamp, and posterior-segment evaluation with condensing lenses. All examinations were performed by an ophthalmologist or trained ophthalmology residents. Participants also underwent CS test using the MARS numeral CS chart. Tests were conducted in the low-vision clinic with standard room illumination and placed on a reading stand. All subjects over 40 years of age were provided with a +2.00 D near addition, as per the manufacturer's recommendation (10). Subjects were further categorized as normal or DM based on their HbA1c levels. The definition to diagnose them was based on the guidelines provided by the American Diabetes Association of HbA1c value of >6.5%.

### Study Variables

Age, gender, education, VA, CS, and DM status were considered as predictors. Age was classified into 4 groups (<18 years old, 18-40 years old, 41-64 years old, and >65 years old), and gender was classified into female and male. Education was classified as elementary school, junior high school, senior high school and undergraduate. Visual acuity was classified into 4 groups (<3/60 LogMAR >1.30; 3/60-6/60 LogMAR 1.10-1.30; 6/40-6/24 LogMAR 1.00-0.60, 6/18-6/6 LogMAR 0.50-0.00). Contrast sensitivity can be categorized into 4 groups (<0.48 as profound, 0.52-1.00 as severe, 1.04-1.48 as moderate and 1.52-1.76 as normal). As for diabetic related findings, we classified into DM and non DM group based on their HbA1c level.

### Study Analysis

SPSS for Mac version 26.0 was used for statistical analysis (SPSS, Chicago, IL, USA). Since the data were not normally distributed, Fisher's exact test was employed to compare VA and CS based on DM status. Spearman correlations were assessed between DM status in ESRD patients with VA and CS.

## Results

### Demographic Characteristics

The number of samples that met the inclusion criteria was 100 patients (185 eyes). Of 100 patients, 51 (51%) were male, and 49 (49%) were female. The mean age of the study group was 47±12.8 (15-76) years, with 39% had completed senior high school as their highest level of education. As for the DM status, we found 80 (80%) patients without DM. Based on the inclusion criteria, data for VA and CS were analyzed for 34 eyes with DM and 151 without DM. Posterior segment examination revealed that normal fundus findings were the most common finding, accounting for 98 eyes (53.0%) (Table 1).

Table 1. Demographic characteristics of hemodialysis patients

| Characteristic | Value |
|---|---|
| Age (mean±SD) | 47 ± 12.8 (15-76) |
| Sex (n,%) | |
| Female | 49 (49.0 %) |
| Male | 51 (51.0 %) |
| Basic compulsory education (n,%) | |
| Elementary school | 15 (15.0%) |
| Junior high school | 21 (21.0%) |
| Senior high school | 39 (39.0%) |
| Undergraduate | 22 (22.0%) |
| NA | 3 (3.0%) |
| Diabetes Mellitus status (n,%) | |
| Diabetes Mellitus | 20 (20.0%) |
| Non Diabetes Mellitus | 80 (80.0%) |
| Visual acuity (LogMAR) (n,%) | |
| >1.30 | 10 (5.4%) |
| 1.10-1.30 | 0 (0%) |
| 1.00-0.60 | 9 (4.9%) |
| 0.50-0.00 | 166 (89.7%) |
| Contrast sensitivity (LogCS) | |
| <0.48 | 5 (2.7%) |
| 0.52 – 1.00 | 4 (2.2%) |
| 1.04 – 1.48 | 34 (18.4%) |
| >1.52 | 142 (76.7%) |
| Posterior segment findings (n,%) | |
| Normal | 98 (53.0%) |
| Non-proliferative diabetic retinopathy | 16 (8.6%) |
| Proliferative diabetic retinopathy | 6 (3.2%) |
| Hypertensive vasculopathy | 40 (21.6%) |
| Hypertensive retinopathy | 6 (3.2%) |
| Central retinal vein occlusion | 1 (0.5%) |
| Others (macular abnormality) | 7 (3.8%) |
| Difficult to evaluate | 7 (3.8%) |
| NA | 4 (2.2%) |

*NA: Not Available*

**Visual Acuity Measurements**

Based on the results of data collection, BCVA was found based on LogMAR value >1.30 in 5 (14.7%) DM patients and 5 (3.3%) in non-DM patients, LogMAR value 1.00-0.60 in 3 (8.8%) of DM patients and 6 (4.0%) with non-DM patients, while the LogMAR value was 0.50-0.00 in 26 (76.5%)

DM patients and 140 (92.7%) in non-DM patients. In both groups, most of the VA was in the 0.50-0.00 (Table 2). Table 1 shows significant difference in VA between groups (p=0.003).

Table 2. Visual acuity of the ESRD patients undergoing hemodialysis in the DM and non-DM groups

| No | Visual Acuity (LogMAR) | With DM (%) | Without DM (%) | *p*-value |
|---|---|---|---|---|
| 1 | >1.30 | 5 (14.7) | 5 (3.3) | 0.003 |
| 2 | 1.10-1.30 | - | - | |
| 3 | 1.00-0.60 | 3 (8.8) | 6 (4.0) | |
| 4 | 0.50-0.00 | 26 (76.5) | 140 (92.7) | |

Contrast Sensitivity Measurements

Contrast sensitivity was found based on Log CS value < 0.48 in 2 (5.9%) DM patients and 3 (2.0%) in non-DM patients. Log CS value 0.52-1.00 in 3 (8.8%) DM patients and 1 (0.7%) in non-DM patients. Log CS value 1.04-1.48 in 13 (38.2%) of DM patients and 21 (13.9%) in non-DM patients. Log CS value >1.52 in 16 (47.1%) of DM patients and 126 (83.4%) in non-DM patients. In both groups, the highest CS was found to be at category >1.52 (Table 3). Table 3 shows that in the DM group, the majority of CS was 1.04-1.48 and >1.52 yet for the non-DM group, more than two-thirds of patients had CS of >1.52. The difference in CS between groups was significant (p= 0.000).

Table 3. Contrast sensitivity of the ESRD patients undergoing hemodialysis in the DM and non-DM group

| No | Contrast sensitivity (LogCS) | With DM (%) | Without DM (%) | *p*-value |
|---|---|---|---|---|
| 1 | <0.48 | 2 (5.9) | 3 (2.0) | 0.000 |
| 2 | 0.52 – 1.00 | 3 (8.8) | 1 (0.7) | |
| 3 | 1.04 – 1.48 | 13 (38.2) | 21 (13.9) | |
| 4 | >1.52 | 16 (47.1) | 126 (83.4) | |

Spearman's correlation test revealed a strong correlation of VA and CS (r= 0.63) in all groups. The correlation between VA and CS in the DM group was r=0.644. Similarly, the correlation between VA and CS in the non-DM group was r=0.573.

Discussion

In the present study, VA and CS were significantly different between ESRD patients with and without DM undergoing HD. DM may contribute to neuroretinal dysfunction and microvascular changes even before severe retinal abnormalities become clinically apparent. Therefore, the observed differences in visual function may also reflect multifactorial systemic and retinal changes associated with DM and ESRD.

The study population had a mean age of 47 years and an almost equal sex

distribution, reflecting the demographic profile of ESRD patients undergoing HD in our center. Most participants had completed minimum senior high school as their highest level of education. Although educational level was not specifically analyzed in relation to visual outcomes, previous studies have suggested that higher educational attainment may indirectly influence health outcomes through health literacy, a factor associated with improved disease knowledge and self-management in patients with chronic kidney disease (11). These factors could contribute to the relatively favorable visual acuity and contrast sensitivity profiles observed in the present cohort.

Most patients in this study did not have DM, reflecting the heterogeneous etiologies of ESRD in our population. Posterior segment examination revealed that normal fundus findings were the most common observation, followed by hypertensive vasculopathy, whereas DR was observed in a smaller proportion of eyes. These findings suggest that retinal vascular changes related to systemic hypertension may be more prevalent than diabetes-related retinal abnormalities in this HD cohort, which is consistent with previous studies including previous reports among Indonesian HD patients demonstrated a relatively low prevalence of advanced DR (12,13).

The percentage of patients with better vision (0.50-0.00) in the current study was found to be higher in the non-DM group. A study by Mansour et al., also reported a similar result, that more than half of patients had good VA (14). Our study also reported that the VA of ESRD patients was significantly different between DM and non-DM groups (p=0.003). However, a different finding was found in Duran et al., study which analyzed 368 eyes and was divided into three groups: disease-free, DM patients without diabetic retinopathy (DR), and DM patients with DR. They observed no statistically significant difference in VA among groups (14). The different findings might be due to in our study, diabetic macular oedema was not part of exclusion criteria yet in Durán et al., study no patients had clinically significant macular oedema (14). It is well documented that the major cause of significant vision loss in diabetic patients is fluid buildup in the posterior pole.

As chronic kidney disease (CKD) progresses slowly, ocular abnormalities are frequently overlooked. Study conducted by Widjaja SA et al., showed that high prevalence of ocular abnormalities among HD patients were revealed. Cataract and conjunctival and corneal calcification (CCC) were found to be the major ocular abnormalities in HD patients and are potentially reversible if addressed early (13). Thus, ocular screening is essential in these patients for early detection and appropriate intervention to prevent further loss of vision (9,15–17).

Contrast sensitivity can be used as an early sign of retinal abnormalities that are not reflected by assessments of VA. Our study used the MARS numeral chart to assess CS. The MARS chart shows good validity and reasonable agreement with the Pelli-Robson chart (16). Our study observed that in the DM group, the percentage of patients who had better CS was higher compared to non-DM group. The difference in CS in DM and non-DM group was statistically significant. This finding is in agreement with a study by Duran et al., that the difference in CS was significant

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between control group and DM patients with non-proliferative DR (14). Chande et al., observed reduced CS not only found in DM group but also in prediabetes group (18).

Reduced CS in prediabetes suggests that magnocellular and parvocellular pathways may be compromised in impaired fasting glucose states (18). Changes in retinal function as a result of alterations in glucose metabolism, as shown by glycosylated haemoglobin, are responsible for the dysfunction evident in DM (19). The present study also observed a strong correlation between VA and CS in both DM and non-DM groups. CS is more sensitive than VA in detecting early ganglion cell and inner plexiform layer dysfunction, which is common in diabetic and uremic neuropathy. Diabetic patients on HD may experience retinal neurodegeneration even before vascular changes become evident. Therefore, it is suggested that CS assessment in DM individuals without retinopathy may be able to recognize early preclinical changes (20).

The fact that these tests are readily available at ophthalmology centers is a strength of the present study. It may provide valuable information for early detection and prompt intervention to prevent further loss of vision, especially in CKD populations. Our study provides vital information about the comparison of VA in ESRD patients undergoing HD based on DM status from underserved areas in the tertiary hospital as a national referral center hospital. Further, in our tertiary center, most patients are referred from peripheral centers for specialist opinion for refractory disease, complications, or for receiving HD. Hence, patients' conditions are mostly high-morbidity, but we managed to give maximal treatment to the patients. However, this research could present the data of VA and CS faced by most tertiary HD centers.

Several limitations should be considered when interpreting the findings of this study. First, due to the study's exclusion criteria, patients with ESRD who had media opacities (e.g., cataract or vitreous hemorrhage) were not included in the analysis. Consequently, the collected data did not encompass CKD patients with cataracts or vitreous opacities, conditions that are frequently encountered in routine clinical practice, thereby limiting the generalizability of our findings. Second, DR severity was not included in a separate subgroup analysis because of its low prevalence within the study population. As a result, stratification according to DR severity was not feasible, limiting our ability to assess the differential effects of mild and advanced stages of the disease on visual function. Given that increasing DR severity has been associated with greater impairment in visual acuity and contrast sensitivity, the inability to account for this factor may have introduced residual confounding into our findings. Therefore, the observed associations should be interpreted with caution, and future studies with a larger number of participants across different DR severity levels are warranted to better elucidate the impact of DR severity on visual outcomes. Finally, the cross-sectional nature of the study limits the ability to establish causal or temporal relationships among visual function, kidney disease, and DM. Despite these limitations, our findings provide important preliminary evidence and a basis for future longitudinal studies aimed at elucidating the complex interplay between

visual acuity, contrast sensitivity, CKD, and DM.

## Conclusion

This study revealed that VA and CS in ESRD patients undergoing HD with DM had significant differences from those without DM. A strong correlation between VA and CS was observed in both groups. Regular VA and CS assessment helps monitor DR progression and guide timely intervention. Impaired CS is associated with difficulty in low-contrast conditions which affects overall quality of life. Hence, monitoring VA and CS in HD patients with DM provides early detection of vision-threatening changes, helps prevent severe visual impairment, and improves patients' quality of life. However, given the complex interplay between diabetes, ESRD, retinal abnormalities, and visual function, further investigation is needed to better elucidate these relationships.

## Declarations

### Statement on the Use of Artificial Intelligence

Artificial Intelligence was used to assist in drafting the declarations section. Information regarding any additional use of artificial intelligence in the research or manuscript preparation has not been provided.

### Author contribution statement

The authors of this study are Muhammad Firmansjah, Togar Erkasan Sitorus, Wimbo Sasono, Sauli Ari Widjaja, Ima Yustiarini, Ady Dwi Prakosa, Widodo, and Ria Sandy Deneska. Their individual contributions have not yet been specified and require confirmation from the authors.

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### Conflict of interest

Conflict-of-interest disclosures have not been provided. The authors must confirm the presence or absence of any financial or non-financial conflicts of interest related to this study.

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