

## Article

# Patient-Reported Outcomes Reveal Impairments Not Explained by Psychophysical Testing in Patients With Regressed PDR

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**Purpose:** We evaluated the correlations between visual deficits and patient-reported symptoms in patients with regressed proliferative diabetic retinopathy (PDR) to determine whether there is a psychophysical basis for vision-related impairments.

**Methods:** Visual acuity, reading acuity, contrast sensitivity, frequency doubling perimetry (FDP), Humphrey field analyzer (HFA), and dark adaptation assessed visual function. The National Eye Institute Vision Function Questionnaire-25 (NEI VFQ-25) and Low Luminance Questionnaire (LLQ) assessed quality of life.

**Results:** We recruited 30 adults who received panretinal photocoagulation (PRP) for PDR and 15 control subjects; 22 diabetic and 11 control participants completed a second evaluation 5 years later. Visual acuity of the worse-seeing eyes tended to correlate better with NEI VFQ-25 and LLQ than did the acuity of the better-seeing eyes. Other vision measures were generally not associated with either questionnaire, especially responses related to driving ability and mental health. Visual acuity only detected subnormal performance in 43% to 45% of patients, while FDP 24-2, HFA 60-4, and LLQ detected abnormal performance in >80% of patients.

**Conclusions:** Poor visual acuity may explain some vision-related impairments in daily function. However, many patients with regressed PDR have normal acuity but reduced visual field and poor quality of life. In these patients, their reported symptoms were not fully explained by visual acuity or any psychophysical tests alone.

**Translational Relevance:** Visual acuity is a poor indicator of overall visual function in people with regressed PDR. In clinical settings, visual field tests and patient-reported outcomes may provide more comprehensive assessments of their functional deficits than visual acuity.

## Introduction

Diabetic retinopathy (DR) is a leading cause of vision loss in the world.<sup>1</sup> The estimated prevalence of DR is about 93 million people, including 17 million with proliferative diabetic retinopathy (PDR).<sup>2</sup> Since the Diabetic Retinopathy Study in 1970s, panretinal photocoagulation (PRP) has been the standard treatment for PDR, which greatly reduces the risk of severe vision loss. However, it also causes permanent damage to the peripheral retina that can impair central and peripheral vision.<sup>3,4</sup> With the loss of vision, these patients also reported low health-related quality of life and impaired daily function.

In recent years, the Diabetic Retinopathy Clinical Research Network published multiple reports that demonstrated loss of visual acuity and visual field along with poor vision-related quality of life, as measured by the National Eye Institute Vision Function Questionnaire-25 (NEI VFQ-25) and Low Luminance Questionnaire (LLQ), in patients who had received PRP for PDR.<sup>5-7</sup> The NEI VFQ-25 was first developed to assess the quality of life across various ocular disease, whereas the LLQ was specifically designed to measure functional impairments at dim lighting and at night.<sup>8,9</sup> In addition, previous studies have revealed reductions in health-related quality of

life in people with diabetes and the early stage of DR.<sup>10–12</sup>

To date, however, no study has investigated whether patient-perceived difficulty in vision-related daily activities after PRP could be explained by their visual deficits. This report provides the first insight into the relationship between visual functions (visual acuity, reading acuity, contrast sensitivity, visual field, dark adaptation, and photostress recovery) and patient-reported outcomes (PROs) (NEI VFQ-25 and LLQ scores) in this population. It also explores whether visual impairments measured by visual acuity and other psychophysical tools could explain the reduced quality of life assessed by NEI VFQ-25 and LLQ. The clinical significance of the study is to shed light on whether other vision measures provide additional information about the visual deficits of the person beyond what is detected by visual acuity.

## Methods

The study was conducted at the University of Michigan W. K. Kellogg Eye Center with approval from University of Michigan Medical School Institutional Review Board, and it adhered to the tenets of Declaration of Helsinki and Health Insurance Portability and Accountability Act. The study took place between August 2012 and September 2018.

### Patients and Examination

The study recruited adults with diabetes who received PRP for PDR (post-PRP group) and age-matched controls based on the inclusion and exclusion criteria previously described by Boynton et al.,<sup>13</sup> which are briefly outlined here: (1) Post-PRP participants were older than 18 years old, previously diagnosed with diabetes, received PRP for PDR at least 6 months prior to enrollment, and had no other ocular pathology, such as clinically significant macular edema. (2) Control participants were older than 18 years and had no diabetes or any diseases that impaired their vision. In each participant, one eye was selected as the study eye. If both eyes were eligible, then the eye with the better visual acuity was chosen. If they had equal acuity, then the right eye was used.

In the study, participants completed a baseline assessment and, after 5 years, underwent a follow-up assessment. For each visit, the study eye received a comprehensive ophthalmologic examination to assess its central and peripheral vision as previously described.<sup>13</sup> After refraction, best-corrected visual

acuity was measured with an electronic visual acuity tester using a Snellen chart. For a subanalysis, visual acuity of nonstudy eyes was also collected from the electronic health record from a visit within 3 months of the study visit. The study and nonstudy eyes were sorted into the better-seeing and worse-seeing eyes based on their visual acuity. Next, reading acuity was examined with the Minnesota Reading Test (MNREAD). Contrast sensitivity was measured using a contrast sensitivity chart (Pelli-Robson; Haag-Streit USA, Mason, OH). Matrix perimeter (Carl Zeiss Meditec, Dublin, CA) performed the frequency doubling perimetry (FDP) 24-2 full-threshold protocol. A Humphrey field analyzer (HFA) (II-750; Carl Zeiss Meditec) performed the photopic central 10-2 Swedish Interactive Threshold Algorithm standard and peripheral 60-4 threshold protocols. FDP 24-2 and HFA 10-2 results were depicted as mean deviation (MD), pattern standard deviation (PSD), and foveal sensitivity (FS). MD represents the overall depression of the visual field relative to the normal reference. PSD represents the overall deviation of the measured visual field from the normal hill of vision.<sup>14</sup> A dark adaptometer (Adapt Dx; MacuLogix, Hummelstown, PA) measured the dark adaptation speed.

Though the results were not reported by Boynton et al.<sup>13</sup> in the baseline report, vision-related quality of life was measured with the NEI VFQ-25 and the LLQ at both visits. The NEI VFQ-25 consists of 12 subscales: general health, general vision, near vision, distance vision, driving, peripheral vision, color vision, ocular pain, and vision-specific tasks such as role difficulties, dependency, social functioning, and mental health. Some subscales, including general health, color vision, ocular pain, role difficulties, and dependency were excluded from the analysis. The LLQ consists of six subscales: driving, extreme lighting conditions, mobility, emotional distress, general dim lighting, and peripheral vision. The subscale and composite scores were calculated with methods described by the developers.<sup>8,9</sup>

### Statistical Analysis

Data analysis was performed using statistical software (SPSS Statistics; version 25.0; SPSS, Inc., Chicago, IL). Continuous variables were expressed as mean and standard deviation. Scatter plots were used to check for normal distribution. Spearman's rank order correlation test were used to determine linear relationship between two continuous or ordinal variables when applicable. Given that a large number of variables were compared in the correlation

**Table 1.** Subject Characteristics at the Baseline and Follow-Up Visits

| Characteristics                       | Control         |                 | Post-PRP PDR    |                 |
|---------------------------------------|-----------------|-----------------|-----------------|-----------------|
|                                       | Baseline        | Follow-Up       | Baseline        | Follow-Up       |
| Sex, no. (%)                          |                 |                 |                 |                 |
| Female                                | 6 (40)          | 5 (45)          | 12 (40)         | 6 (27)          |
| Male                                  | 9 (60)          | 6 (55)          | 18 (60)         | 16 (73)         |
| Diabetes type, no. (%)                |                 |                 |                 |                 |
| T1DM                                  |                 |                 | 22 (73.3)       | 15 (68)         |
| T2DM                                  |                 |                 | 8 (26.7)        | 7 (32)          |
| Age, mean $\pm$ SD, y                 | 56.2 $\pm$ 17.7 | 63.7 $\pm$ 15.1 | 58.6 $\pm$ 13.4 | 65.0 $\pm$ 14.5 |
| Diabetes duration, mean $\pm$ SD, y   |                 |                 | 36.4 $\pm$ 12.4 | 40.6 $\pm$ 10.8 |
| Years since PRP, mean $\pm$ SD        |                 |                 | 13.4 $\pm$ 8.3  | 18.6 $\pm$ 8.4  |
| HbA1c, mean $\pm$ SD, %               | 5.5 $\pm$ 0.3   | 5.6 $\pm$ 0.3   | 7.43 $\pm$ 1.24 | 7.84 $\pm$ 1.28 |
| BMI, mean $\pm$ SD, kg/m <sup>2</sup> | 27.3 $\pm$ 7.7  | 28.6 $\pm$ 9.1  | 30.3 $\pm$ 5.7  | 30.2 $\pm$ 7.1  |

T1DM, type 1 diabetes mellitus; T2DM, type 2 diabetes mellitus, BMI, body mass index.

analysis, the statistical significance was defined as  $P < 0.01$  to reduce the chance of type 1 errors.

## Results

**Table 2.** Correlations Between Visual Acuity and Other Visual Function Outcomes in Patients with PRP

| Visual Function      | Visual Acuity |                  |
|----------------------|---------------|------------------|
|                      | <i>r</i>      | <i>P</i> Value   |
| Contrast sensitivity | −0.37         | 0.042            |
| Reading acuity       | <b>0.70</b>   | <b>&lt;0.001</b> |
| FDP 24-2             |               |                  |
| MD                   | −0.26         | 0.169            |
| PSD                  | 0.29          | 0.124            |
| FS                   | −0.37         | 0.044            |
| HFA 10-2             |               |                  |
| MD                   | −0.41         | 0.027            |
| PSD                  | <b>0.47</b>   | <b>0.010</b>     |
| FS                   | <b>−0.54</b>  | <b>0.002</b>     |
| HFA 60-4 total       | −0.37         | 0.043            |
| Dark adaptation      | <b>0.52</b>   | <b>0.003</b>     |

Results of the Spearman's rank order correlation test. Correlation is statistically significant,  $P < 0.01$  and in bold. Visual acuity significantly correlated with other central vision assessments, including reading acuity, HFA 10-2, and dark adaptation. Although the macular visual function was grossly depressed, the patterns of visual deficit measured by contrast sensitivity and FDP 24-2 were only weakly associated with the loss of visual acuity. These findings suggest that FDP 24-2 and contrast sensitivity may detect additional visual deficit that is not measured by visual acuity assessment.

At the baseline, 45 participants were enrolled, including 30 adults with diabetes who received PRP for PDR (post-PRP group) and 15 healthy adults (control group) (Table 1). A majority of the post-PRP patients were men (60.0%) with a mean (SD) age of 58.6 (13.4) years old and had type 1 diabetes (73.3%) with a mean (SD) duration of 36.4 (12.4) years. Of note, 29 of 30 patients received bilateral PRP prior to enrollment, with the study eyes initially treated with PRP, on average, 13.4 (range: 1.0–32.0) years ago. After 5 years, 22 post-PRP patients completed a second evaluation, and most patients had stable vision (see Supplementary Table S1 for the results of psychophysical assessments and PROs). Only one patient received supplemental PRP between the visits. There was also no statistically significant change in hemoglobin A1c or body mass index between the visits in these patients.

### Visual Function and PROs

To evaluate the relationships between visual acuity and other psychophysical assessments in the diabetic group, we performed the correlation analysis using the baseline data (Table 2). Visual acuity was moderately correlated with reading acuity ( $r = 0.70$ ;  $P < 0.001$ ), HFA 10-2 FS ( $r = -0.52$ ;  $P = 0.002$ ), and dark adaptation ( $r = 0.52$ ;  $P < 0.003$ ). It also showed weak associations with contrast sensitivity ( $r = -0.37$ ;

**Table 3.** Correlations Between Visual Function Outcomes and LLQ and NEI VFQ-25 for Post-PRP PDR

| Patient-Reported Outcomes | Visual Acuity |                | FDP 24-2 PSD |                | Dark Adaptation |                |
|---------------------------|---------------|----------------|--------------|----------------|-----------------|----------------|
|                           | <i>r</i>      | <i>P</i> Value | <i>r</i>     | <i>P</i> Value | <i>r</i>        | <i>P</i> Value |
| <b>LLQ</b>                |               |                |              |                |                 |                |
| Extreme lighting          | -0.05         | 0.013          | -0.39        | 0.034          | -0.25           | 0.183          |
| Mobility                  | -0.19         | 0.305          | -0.45        | 0.014          | 0.02            | 0.899          |
| Emotional distress        | -0.14         | 0.472          | -0.29        | 0.125          | -0.06           | 0.736          |
| Dim lighting              | -0.29         | 0.124          | -0.4         | 0.028          | -0.08           | 0.682          |
| Peripheral vision         | -0.09         | 0.630          | <b>-0.52</b> | <b>0.003</b>   | -0.18           | 0.346          |
| Driving                   | -0.33         | 0.081          | -0.25        | 0.196          | -0.15           | 0.440          |
| <b>NEI VFQ-25</b>         |               |                |              |                |                 |                |
| General vision            | -0.11         | 0.552          | -0.25        | 0.181          | -0.31           | 0.100          |
| Near activities           | -0.39         | 0.031          | <b>-0.47</b> | <b>0.009</b>   | -0.17           | 0.362          |
| Distance activities       | -0.24         | 0.208          | -0.4         | 0.03           | -0.07           | 0.721          |
| Social functioning        | -0.26         | 0.174          | 0            | 1              | -0.01           | 0.953          |
| Mental health             | -0.35         | 0.061          | -0.3         | 0.108          | -0.16           | 0.393          |
| Peripheral vision         | 0.09          | 0.641          | -0.35        | 0.058          | 0.07            | 0.728          |
| Driving                   | -0.22         | 0.252          | -0.22        | 0.243          | -0.05           | 0.810          |

Results of the Spearman's rank order correlation test. Correlation is statistically significant if  $P < 0.01$  and is in bold. Visual acuity correlated with LLQ extreme lighting and NEI VFQ-25 near activities subscales. FDP 24-2 PSD had highest correlation coefficients with LLQ peripheral vision and NEI VFQ-25 near activities subscales. Visual acuity showed weak association with LLQ extreme lighting ( $P = 0.013$ ) and NEI VFQ-25 near activities subscales ( $P = 0.031$ ), though is not statistically significant. In contrast, dark adaptation showed no significant correlation with any subscales.

$P = 0.042$ ), FDP 24-2 FS ( $r = -0.37$ ;  $P = 0.044$ ), and HFA 60-4 total threshold ( $r = -0.37$ ;  $P = 0.043$ ). These findings indicate that contrast sensitivity, FDP 24-2, and HFA 60-4 detect additional vision loss that is not measured by visual acuity.

We also evaluated correlations between visual function and LLQ and NEI VFQ-25 scores (Table 3). Given its exploratory nature, we first assessed the associations using the composite scores of the questionnaires. Unlike other vision measures, only FDP 24-2 PSD appeared to correlate with the composite scores of LLQ ( $r = -0.43$ ;  $P = 0.018$ ) and NEI VFQ-25 ( $r = -0.37$ ;  $P = 0.043$ ). Then, we examined its associations with the subscales (Table 3). In the analysis, we also included visual acuity and dark adaptation response based on the results from previous studies, which showed that these measures were correlated with PROs.<sup>9,10,12,15</sup> FDP 24-2 PSD was significantly correlated with LLQ peripheral vision ( $r = -0.52$ ;  $P = 0.003$ ) and NEI VFQ-25 near activities ( $r = -0.47$ ;  $P = 0.009$ ). Visual acuity showed weak correlation with LLQ extreme lighting ( $r = -0.45$ ;  $P = 0.013$ ) and NEI VFQ-25 near activities ( $r = -0.39$ ;  $P = 0.031$ ), although it was not statistically significant. On the other hand, dark adaptation showed no significant association with any subscales.

To be comprehensive, we also assessed the relationship among other visual functions (contrast sensitivity, reading acuity, FDP 24-2, HFA 10-2, and HFA 60-4) and NEI VFQ-25 and LLQ subscales. Interestingly, none of these assessments were associated with the driving subscales and subscales related to mental health and social functioning ( $P > 0.05$ ). These findings suggest that only some patient-reported symptoms were associated with certain visual deficits. In addition, symptoms related to mental distress and driving ability may offer additional information about the functional impairments of the individual beyond what is measured objectively by the psychophysical tests.

We also organized the visual acuity of the study and nonstudy eyes into better-seeing and worse-seeing eyes based on acuity to determine which eye is better correlated with PROs (Table 4). At the baseline, 23 of 30 study eyes were the better-seeing eyes and seven were the worse-seeing eyes. The mean (SD) visual acuity (logMAR) of the better-seeing eyes was 0.10 (0.14). The mean (SD) visual acuity of the worse-seeing eye was 0.23 (0.21). The results showed that almost all LLQ and NEI VFQ-25 scores had higher correlation coefficients with the worse-seeing eyes than with the better-seeing eyes. These results suggest

**Table 4.** Correlations Between LLQ and NEI VFQ-25 Scores and Visual Acuity in the Better- and Worse-Seeing Eyes for Post-PRP PDR

| Patient-Reported Outcomes | Better-Seeing Eye |                | Worse-Seeing Eye |                  |
|---------------------------|-------------------|----------------|------------------|------------------|
|                           | <i>r</i>          | <i>P</i> Value | <i>r</i>         | <i>P</i> Value   |
| <b>LLQ</b>                |                   |                |                  |                  |
| Composite                 | -0.37             | 0.045          | <b>-0.66</b>     | <b>&lt;0.001</b> |
| Extreme lighting          | -0.38             | 0.04           | <b>-0.65</b>     | <b>&lt;0.001</b> |
| Mobility                  | -0.25             | 0.176          | <b>-0.57</b>     | <b>0.001</b>     |
| Emotional distress        | -0.34             | 0.065          | <b>-0.59</b>     | <b>0.001</b>     |
| Dim lighting              | -0.36             | 0.049          | <b>-0.59</b>     | <b>0.001</b>     |
| Peripheral vision         | -0.26             | 0.162          | -0.4             | 0.027            |
| Driving                   | -0.43             | 0.019          | <b>-0.69</b>     | <b>&lt;0.001</b> |
| <b>NEI VFQ-25</b>         |                   |                |                  |                  |
| Composite                 | -0.43             | 0.017          | <b>-0.75</b>     | <b>&lt;0.001</b> |
| General vision            | -0.26             | 0.165          | -0.28            | 0.135            |
| Near activities           | -0.37             | 0.043          | <b>-0.62</b>     | <b>&lt;0.001</b> |
| Distance activities       | -0.37             | 0.044          | <b>-0.63</b>     | <b>&lt;0.001</b> |
| Social functioning        | -0.32             | 0.089          | <b>-0.52</b>     | <b>0.003</b>     |
| Mental health             | -0.36             | 0.054          | <b>-0.66</b>     | <b>&lt;0.001</b> |
| Peripheral vision         | -0.19             | 0.308          | -0.44            | 0.015            |
| Driving                   | -0.35             | 0.065          | <b>-0.63</b>     | <b>&lt;0.001</b> |

Results of the Spearman's rank order correlation test. Correlation is statistically significant,  $P < 0.01$  and in bold. In comparison, LLQ and NEI VFQ-25 outcomes showed stronger linear relationships with visual acuity of the worse-seeing eye than with visual acuity of the better-seeing eye.

that the worse-seeing eyes may have a stronger impact on the quality of life in this patient population than the better-seeing eyes.

### Detection Rate

Overall, we assessed multiple aspects of visual function and quality of life and how they were affected by PDR and PRP. The [Figure](#) illustrates the number of post-PRP patients whose performance fell outside the reference ranges, defined as the mean performance of the control group plus or minus 2 SD, depending on which direction was considered worse performance. At the baseline, FDP 24-2 PSD and HFA 60-4 total threshold detected subnormal performance in 97% of the patients with diabetes, whereas reading acuity detected only 20% with below normal performance. (See [Supplementary Table S2](#) for the percentage of patients with PRP who performed below normal.) At the follow-up, FDP 24-2 PSD and

HFA 60-4 total threshold also detected many abnormal outcomes, at 91% and 93%, respectively. On the other hand, visual acuity found 43% and 45% of post-PRP subjects with subnormal performance at the baseline and follow-up, respectively. These findings show that FDP and HFA are more sensitive at identifying vision loss in these patients than visual acuity alone. As for PROs, LLQ detected abnormal composite scores in 81% to 90% of patients, which was more sensitive than NEI VFQ-25 (53%–57% of patients).

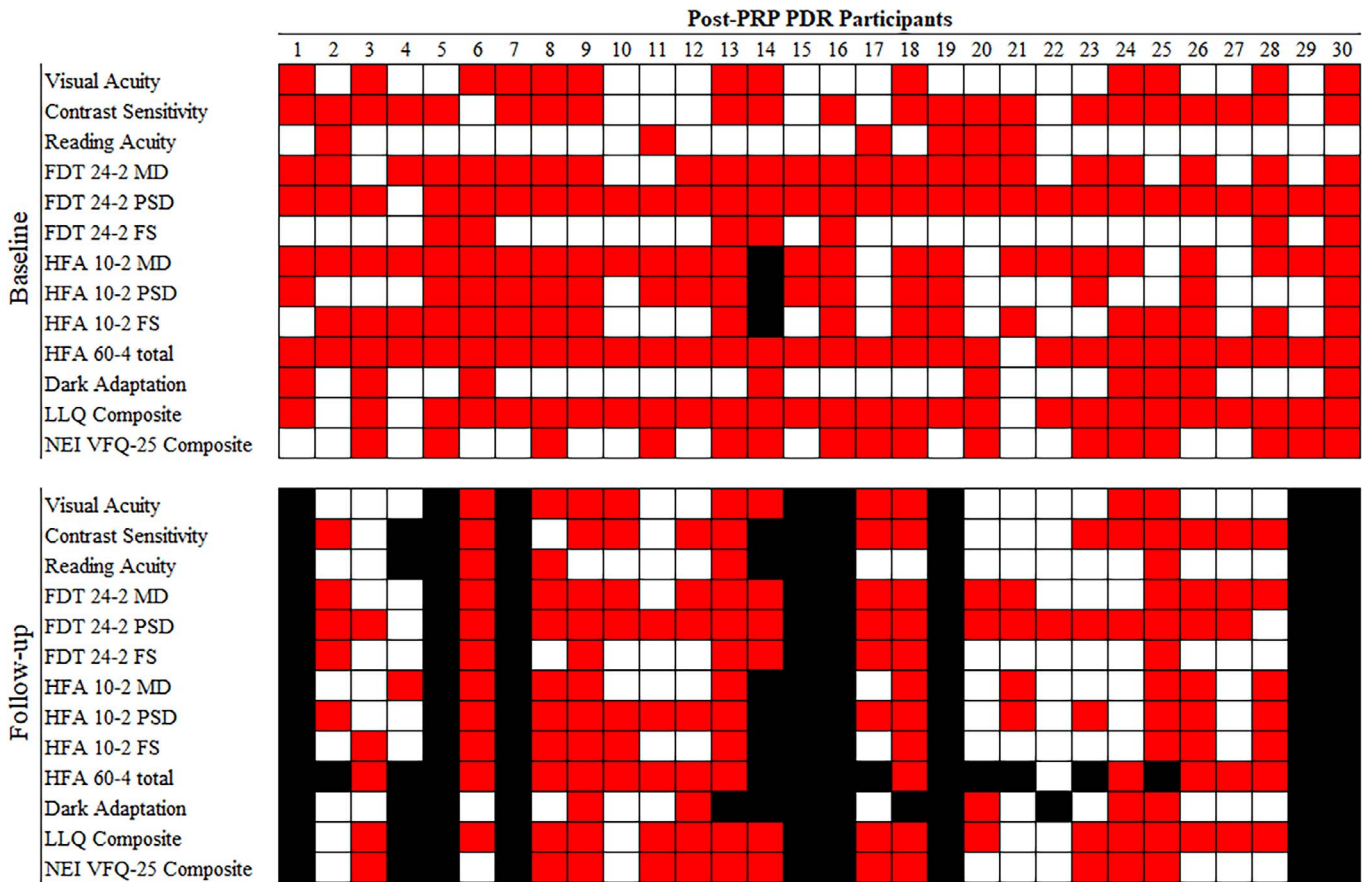
It was also demonstrated that the pattern of visual impairments varied between individuals ([Figure](#)). For instance, patient no. 5 had abnormal performance on contrast sensitivity but normal visual acuity, whereas patient no. 6 had poor visual acuity but normal contrast sensitivity. Taken together, these results showed that there is no linear order of vision loss, so different aspects of vision can be compromised independently in patients with PDR treated with PRP.

## Discussion

Even after PRP, patients with regressed PDR had loss of central and peripheral vision, and many reported a poor health-related quality of life. In this report, we revealed that some of their symptoms, such as driving impairment and mental distress, are not explained by the visual deficits measured with the psychophysical tests. In addition, we found that assessments such as FDP 24-2, HFA 60-4, and PROs could offer a better evaluation of the visual function deficits and vision-related impairments in these patients than visual acuity alone.

In our cohort, most patients who received PRP for PDR had maintained stable retinopathy and vision. Not surprisingly, a majority of these patients had visual acuity better than or equal to 20/25. However, many of them reported significant loss of central and peripheral vision. Likewise, in the report of the 5-year outcomes of PRP and intravitreal ranibizumab for PDR, Gross et al.<sup>6</sup> also revealed that after 5 years, 84 of 123 eyes treated with PRP and 85 of 117 eyes treated with ranibizumab still maintained a visual acuity better than or equal to 20/25, with group means of 20/25. They also recorded substantial and progressive reductions of visual field in both groups of patients.<sup>6</sup> Overall, these findings suggest that visual acuity is a poor indicator of visual impairments in patients with regressed PDR.

It is of interest that we found LLQ and NEI VFQ



**Figure.** Patients with regressed PDR after PRP who had subnormal performance or PROs. The normal reference range was defined as the mean performance of the control group either plus or minus 2 SD, depending on which direction was considered worse performance. *Red cells* indicate abnormal performance. *White cells* indicate performance within reference range. *Black cells* indicate patients without follow-up. FDP 24-2 PSD and HFA 60-4 total threshold was detected below normal performance in >90% of patients. In contrast, visual acuity found 43% to 45% of patients to have abnormal outcomes. These findings suggest that patients with PRP tend to have more visual field deficits than reduced visual acuity.

responses were better correlated with visual acuity of the worse-seeing eye than with the better-seeing eye. Revick et al.,<sup>16</sup> however, reported that in patients with age-related macular degeneration (AMD), NEI VFQ-25 scores were better associated with visual acuity of the better-seeing eye.<sup>16</sup> These results indicate different patterns of vision impairments in patients with AMD versus those with DR. In addition, it would be expected that the better-seeing eye could compensate for the loss of vision in the worse-seeing eye. However, in patients with advanced DR post PRP, their self-perceived difficulty in daily life and vision-related activities were more influenced by the loss of vision in the worse-seeing eye. This finding may urge current clinical practice to stabilize and improve the vision of the worse-seeing eye in order to achieve an optimal quality of life in these patients. For instance, earlier referral to low-vision services

based on the visual acuity of the worse-seeing eye may maximize its functional utility and improve the general well-being of the individual.<sup>17,18</sup>

In contrast to previous studies, we found that most visual function deficits had no consistent correlation with the declines in PROs. In one study that consisted of patients with varying degrees of DR, Cusick et al.<sup>11</sup> reported that poor visual acuity, contrast sensitivity, and central visual field (HFA 10-2 MD) were associated with lower scores on NEI VFQ-25 near activities. In our study, however, impaired contrast sensitivity and central visual field (FDP 24-2 and HFA 10-2, except FDP 24-2 PSD) were generally not associated with the lower scores on near activities subscale. This difference may be explained by the fact that our patient cohort comprised only individuals with regressed DR treated with PRP, in which PRP may complicate the relationship between vision

deficits and patient-reported symptoms. For instance, despite the fact that most of our patients retained normal visual acuity, many of them reported subnormal responses in the LLQ and NEI VFQ-25.

Next, in a recent report that associated LLQ scores with dark adaptation responses, Yazdanie et al.<sup>15</sup> revealed that in patients with a varying degree of AMD, prolonged dark adaptation responses were linked to lower scores on all LLQ subscales. However, in our cohort, we did not find any significant relationship between dark adaptation responses and LLQ scores. The dark adaptation protocol used in Yazdanie's study and ours assessed rod function in a parafoveal region, as the stimulus was projected to a point 5 degrees above the fovea.<sup>15,19,20</sup> AMD mainly affects central vision, which is assessed by dark adaptation, while PDR and PRP affect both central and peripheral vision as indicated by the reduced performance in FDP 24-2 and HFA 60-4. The global insult of PDR and PRP could complicate the relationship between deterioration in dark adaptation and lower score in LLQ and thus dilute the significance of the correlation.

We also found that loss of central and peripheral visual fields were not associated with response on driving ability in this patient group. The lack of correlation could be explained by the type of information assessed by the LLQ and NEI VFQ-25. Both questionnaires ask about people's self-perceived difficulty in driving, and it is possible that these patients' perceptions on driving ability mismatched their true ability to drive safely on the road. In our cohort, many patients with regressed PDR had excellent visual acuity, such as 20/25, but poor central and peripheral visual field performance. Though a recent study reveals that the loss of peripheral visual field after PRP treatment may not affect people's driving eligibility, there is still a concern for driving safety.<sup>21,22</sup> Prior population-based studies reported that significant loss of central and peripheral vision in drivers who were 65 years and older was associated with poor driving ability and greater risk of motor vehicle collision.<sup>23,24</sup> Hence, it might be important for clinicians to assess visual field in patients with PDR treated with PRP and discuss the potential increased in risk of motor vehicle collision associated with visual field loss.

Earlier studies have also reported that visually impaired patients experienced greater emotional and social distress than do healthy individuals. In these studies, visual impairment was generally defined by poor visual acuity alone.<sup>25,26</sup> In our cohort, however,

many patients had normal visual acuity but reported significant psychological impairment. We also found that most visual deficits were not associated with responses on mental health and social functioning assessed by NEI VFQ-25 and LLQ. In other words, these PROs may provide additional information about the social and emotional impact of PDR and PRP not correlated with psychophysical assessments. It may identify patients with normal visual acuity who could benefit from additional emotional support and, potentially, psychological therapy. In addition, treating the mental disability may improve their daily functioning independent of the visual deficits.<sup>27</sup>

There are several limitations to consider when interpreting this analysis. First, this study has a small sample size, and some subjects were lost to follow-up. Second, the range of PRP treatment (1–32 years ago) and age are quite large, so the applicability of our findings to the general population with severe DR may be limited. Nevertheless, we believe that the findings provide important information about people with regressed PDR after PRP treatment, especially in those with good visual acuity. Third, most visual function parameters showed sporadic correlations, which might be due to the fact that not all of the study eyes were consistently the worse-seeing eye or the better-seeing eye with respect to each visual function assessment. For example, some subjects had excellent visual acuity but had abnormal performance on contrast sensitivity and/or visual field assessments. In other words, different components of vision might be impaired differently by diabetes and/or laser treatment, and the severity of visual impairment also varied with patients and with eyes (of the same patient). Hence, future studies could assess visual function in both eyes and then evaluate how each eye affects vision-related quality of life.

In summary, we found that most psychophysical tools were poor indicators of patient-reported symptoms, especially those related to driving ability and mental health, in patients with regressed PDR after PRP. Even though visual acuity of their worse-seeing eye may explain some of their symptoms, most patients in our cohort had good acuity but poor vision-specific quality of life and restricted visual field. Furthermore, FDP 24-2, HFA 60-4, and/or PROs could detect more patients with visual impairments than visual acuity alone. Hence, it is important to incorporate visual field assessments to better monitor vision loss in patients with advanced DR after laser treatment, which has long been the standard practice in managing patients with glauco-

ma. It also supports the application of PROs in the clinical setting to assess the impact of vision loss in their daily function and general well-being, which may improve their clinical management and achieve better patient outcomes.

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