Clinical Color Vision Testing and Correlation With Visual Function

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• PURPOSE: To determine if Hardy-Rand-Rittler (H-R-R) and Ishihara testing are accurate estimates of color vision in subjects with acquired visual dysfunction.
• DESIGN: Assessment of diagnostic tools.
• METHODS: Twenty-two subjects with optic neuropathy (aged 18–65) and 18 control subjects were recruited prospectively from an outpatient clinic. Individuals with visual acuity (VA) < 20/200 or with congenital color blindness were excluded. All subjects underwent a comprehensive eye examination including VA, color vision, and contrast sensitivity testing. Color vision was assessed using H-R-R and Ishihara plates and Farnsworth D-15 (D-15) discs. D-15 is the accepted standard for detecting and classifying color vision deficits. Contrast sensitivity was measured using Pelli-Robson contrast sensitivity charts.
• RESULTS: No relationship was found between H-R-R and D-15 scores ($P = .477$). H-R-R score and contrast sensitivity were positively correlated ($P = .003$). On multivariate analysis, contrast sensitivity ($\beta = 8.61$, $P < .001$) and VA ($\beta = 2.01$, $P = .022$) both showed association with H-R-R scores. Similar to H-R-R, Ishihara score did not correlate with D-15 score ($P = .973$), but on multivariate analysis was related to contrast sensitivity ($\beta = 8.69$, $P < .001$). H-R-R and Ishihara scores had an equivalent relationship with contrast sensitivity ($P = .069$).
• CONCLUSION: Neither H-R-R nor Ishihara testing appears to assess color identification in patients with optic neuropathy. Both H-R-R and Ishihara testing are correlated with contrast sensitivity, and these tests may be useful clinical surrogates for contrast sensitivity testing. (Am J Ophthalmol 2015;160(3):547–552.

COLOR VISION TESTING IS A ROUTINE PART OF THE neuro-ophthalmologic examination and often is used by comprehensive ophthalmologists to screen for suspected optic neuropathy in patients with new visual complaints. Color vision testing also may be used to diagnose and follow progression of disease and monitor the onset of toxicity from some medications.[1–5] Commonly used and easily accessible color vision tests include the pseudoisochromatic plates, such as the Hardy-Rand-Rittler (H-R-R) and Ishihara tests, and arrangement tests, such as the Farnsworth-Munsell 100 and Farnsworth D-15 hue discrimination test.

Pseudoisochromatic plate testing is inexpensive, readily available, and quickly administered; therefore it is the test of choice that clinicians use in the evaluation of their patients with suspected or known optic neuropathy.[5,6] Pseudoisochromatic plates were originally developed to disclose the color confusion axes of congenital dichromatism (protanopia, deuteranopia, and tritanopia) and function remarkably well at this task.[6] Acquired pseudoisochromatic plate testing defects often do not respect these confusion axes, and clinicians thus assign a score reflecting the number of plates correctly identified. A prior study showed that pseudoisochromatic plate identification in patients with optic neuropathy was worse than expected from visual acuity (VA) loss alone,[5] while another showed that pseudoisochromatic plate test performance declined in concert with reduced visual acuity and/or visual field loss of any etiology.[7]

Arrangement tests require patients to sort colored caps of fixed chroma into a sequence or into groups. These tests are designed without assuming that colors are confused owing to congenital color vision loss, allowing errors to be made across the color circle and between adjacent hues.[1–5,8] Moreover, in contrast to pseudoisochromatic plate testing, arrangement tests allow quantification of severity of disease and may be more sensitive in detecting early visual dysfunction.[5,6,9] Arrangement tests have been demonstrated to be very effective in following and classifying acquired color defects,[4,6,10] but their use has been limited owing to their time-consuming nature.[5,11]

Clinicians often use abnormal pseudoisochromatic plate testing results as evidence for optic neuropathy, and standard clinical teaching reinforces this idea.[12] While patients with optic neuropathy[5,13] and retinal dystrophy[14] often have decreased pseudoisochromatic plate test scores, we have observed that patients with other conditions such as dry eye syndrome also can have abnormal pseudoisochromatic plate test scores. We sought to determine if poor scores on H-R-R and

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TABLE 1. Demographic Data of Patients With Optic Neuropathy and Normal Controls

	Patients (N = 22)	Controls (N = 18)	*P* Value[a]
Mean age in years (SD)	48.0 (10.54)	41.3 (11.5)	.067
Sex, N (%)			.51
Female	13 (61.5)	13 (72.2)	
Male	9 (38.5)	5 (27.8)	
Ethnicity, N (%)			.184
White	16 (72.7)	9 (50)	
Black	4 (18.2)	8 (44.4)	
Asian	1 (.5)	1 (5.6)	
Hispanic	1 (.5)	0 (0)	

[a]*P* values determined by Fisher exact test for sex and ethnicity and *t* test for age.

TABLE 2. Comparison of Visual Function, Including Color Vision Testing, Between Affected Eyes of Patients and Control Eyes

Test Result	Patient Eyes (N = 31)	Control Eyes (N = 36)	$P > \|z\|$
H-R-R score (# of plates correct)[a]	19.1 (1.7)	20.0 (0.1)	.019
Ishihara score (# of plates correct)[a]	15.1 (2.0)	16.0 (0)	.043
D-15 score [15 − (number of errors)][a]	14.6 (0.8)	15.0 (0)	.040
Contrast sensitivity (log units)[a]	1.5 (0.2)	1.7 (0.04)	.003
VA (logMAR)	0.06 (0.2)	0.033 (0.1)	.288

H-R-R = Hardy-Rand-Rittler; VA = visual acuity.

Both eyes of control subjects and the affected eye(s) of patients are included. Mean and standard deviation of each test result are listed. Linear mixed-effects regression models with a random intercept for patients were used to compare the 2 groups. All measures of visual function were reduced in the affected eyes relative to the control eyes, except for visual acuity.

[a]Test with results that are significantly different between patient and control eyes at $\alpha = 0.05$.

Ishihara plate testing represent truly aberrant color vision or indicate a decrement of other psychovisual parameters. We hypothesized that reduced pseudoisochromatic plate test scores would correlate with contrast sensitivity loss and not reflect true color vision defects as determined by color arrangement testing.

METHODS

• **SUBJECTS:** This study was a prospective clinical investigation. All study procedures were approved in advance of the study by the Institutional Review Board of the Johns Hopkins University School of Medicine and adhered to the requirements of the Health Insurance Portability and Accountability Act. Informed consent was obtained from all subjects. Study subjects between ages 18 and 65 were recruited prospectively from the Wilmer Eye Institute at the Johns Hopkins Hospital. Patients with acquired optic neuropathy (glaucoma, ischemic optic neuropathy, optic neuritis, or compressive optic neuropathy) (n = 22) were included. Control subjects (n = 18) had no ocular pathology other than corrected refractive error and had no known neurological disease.

Individuals with best-corrected VA <20/200 at distance or near equivalent or with congenital color vision deficits were excluded (patients and controls). All subjects underwent a comprehensive eye examination, including assessment of best-corrected Snellen acuity, pupillary response, and funduscopy.

• **COLOR VISION TESTING:** Monocular color vision testing was done with H-R-R pseudoisochromatic plates (4th edition; Richmond Products Inc, Albuquerque, New Mexico, USA), Ishihara pseudoisochromatic plates (1997 version; Kanehara & Co, Ltd, Tokyo, Japan), and the Farnsworth D-15 test (PV-16 Quantitative color vision test; Precision Vision, Lasalle, Illinois, USA). The affected eye or eyes of patients and both eyes of control subjects were tested.

Pseudoisochromatic plate testing was done under standardized lighting (basic fluorescent 30 watt bulb) and the plates were held 30 cm away from the patient at a perpendicular angle to the line of sight. The score for the Ishihara test was set as the number of plates identified out of the first 15 screening plates. Scoring followed a standard clinical rubric. For the 1-digit plate, subjects were awarded 1 point for correctly identifying the shown number and 0 points for not seeing or incorrect identification. For the 2-digit plate, subjects were awarded 1 point for correctly identifying both numbers on the plate, half a point for identifying 1 number, and 0 points for not seeing or incorrect identification of both numbers. The score for the H-R-R test was set as the number of plates identified out of the 20 screening and diagnostic plates (numbers 5-24). For plates containing 1 shape, subjects received 1 point for correctly identifying the figure and 0 points for not seeing or incorrect identification. For plates containing 2 shapes, subjects received 1 point for correctly identifying both figures, half a point for identifying 1 shape, and 0 points for not seeing or incorrect identification of both shapes. The Farnsworth D-15 test consists of 15 colored discs comprising the entire color spectrum. Under simulated natural daylight conditions (OttLite 508 illumination, Tampa, Florida), subjects were asked to arrange the discs in order, according to the color, on a