Article ▸ Color Vision Deficiency among Adults Attending a Vision Rehabilitation Clinic

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ABSTRACT

Purpose: Visually impaired (VI) patients have significant ocular disease and may have acquired color vision defects (CVD). There is a scarcity of reports on color vision (CV) testing/CVD prevalence among VI patients in vision rehabilitation clinics (VRC). The purpose of this study was to assess moderate/severe CVD among VI patients and trends related to symptomology, VI, and ocular diagnosis.

Methods: Adults attending a VRC were surveyed regarding CV. Color vision was tested using the 3.3 centimeter stimulus size 'Panel 16 Quantitative Color Vision Test' (D-15). Patients were classified as CVD if there were 2 or more major crossover errors in either eye. Severity of VI was classified based on visual acuity. The primary cause of VI was sub-classified as optic nerve, retina, or other.

Results: Ninety-nine patients completed D-15 testing. VI level in the better-seeing eye ranged between normal/near normal to profound. Nearly half of the patients tested (43.3%) were classified as CVD. The type of CVD could not be assessed in the majority of subjects. The level of VI among those with CVD was 27.9% normal/near normal, 41.9% moderate impairment, and 30.2% severe impairment or worse. A history of CVD was reported by 39% with CVD and 17.3% without CVD. Of those with color vision deficiency, the VI cause was retinal disease in 65.1%, optic nerve disease in 30.2%, and other in 4.7%.

Conclusion: D-15 testing was completed on patients with a wide range of VI levels, demonstrating the feasibility of color vision assessment in a VRC clinic. There was a high percentage of CVD identified. Of those with CVD, there was a range in the level of VI and type of ocular disease identified. Although there is no treatment for CVD, addressing the CVD in the individual rehabilitation plan is recommended and can enhance the practitioner's ability to assist the patient in activities of daily living. Education concerning acquired CVD and specific activities that CVD may impact is essential, especially due to possible progression as the ocular conditions worsen.

Keywords: acquired color vision deficiency, color vision, vision impairment, vision rehabilitation

Introduction

Color vision deficiency (CVD) can be caused by both congenital and acquired mechanisms. Acquired color vision deficiencies can occur from a number of sources, including a wide variety of ocular diseases, systemic disease, systemic medications, trauma, etc.[1-10] It is recognized that acquired color vision defects can be either red-green or blue-yellow, be difficult to classify, affect the right and left eyes asymmetrically, affect males and females equally, and change as the ocular/systemic condition worsens.[1,7,9] Patients with acquired color vision deficiency may or may not be aware of the change to their color vision.

Color vision deficiencies may affect many facets of patients' lives, including education, vocational choices, driving, avocations, socially acceptable clothing color choices, ability to assess preparation of meat or ripeness of fruit, etc.[11,12] Additional testing, rehabilitation, and training of devices may be needed due to possible changes in color perception. Color vision deficiency may affect the ability to spot a colored object when scanning an environment; therefore, this skill may need to be addressed specifically, especially in telescope use.[13,14] Color vision deficiency may also affect the perception of video display unit-generated color displays.[11,15] In addition to standard computer screens, this may include desktop/portable electronic magnifiers or other portable electronic devices. Although there is no treatment for CVD, education about the etiology and prognosis of the CVD is needed since symptomology may also worsen as the ocular condition progresses. Rehabilitation of CVD may include color identifier devices, task lighting, and organizational techniques. Referring eye care professionals and other health care providers, including pharmacists, should be advised so that they can more fully understand their patients' vision.

Color vision is typically assessed clinically using either pseudoisochromatic plates or arrangement tests. The most common pseudoisochromatic plate tests used world-wide are the Ishihara and the Hardy-Rand-Rittler (HHR) plates for both screening and diagnostic testing. Since Ishihara plates

do not test for blue-yellow defects, they cannot be used to assess acquired color vision defects. HRR plates do test for both red-green and blue-yellow color vision defects; however, a false positive rate has been noted both anecdotally and in the literature.[9] Minimum visual acuity needed for HRR interpretation was estimated to be 20/200.[16] Anecdotal evidence suggests that VI patients have difficulty with this test. In addition, pseudoisochromatic plate tests were not developed to correlate to the patients' perception of color in the real world. Arrangement tests (Farnsworth D-15 (D-15) and Farnsworth Munsell 100 (FM100)) were intended to correlate to the perception of surface colors in the real world.[9,17] These tests are typically not used for screening color vision defects. Due to the length of test time and the difficulty in scoring, the D-15 is typically used clinically rather than the FM100. D-15 failure indicates a moderate to severe CVD and suggests that the patient may note difficulty with surface color perception.[9,17,18] Failure on the D-15 does not absolutely indicate difficulty with surface colors or objects; however, those who fail are likely to have an issue.[13,19,20] The D-15 does have a version with larger caps to aid in color vision assessment in the visually impaired, but no minimum visual acuity standards are widely recognized. The larger D-15 may be a better assessment of functional vision. Results from the large D-15 have been shown to be more consistent with color-match data than results from the standard D-15.[21] Since a goal of vision rehabilitation often is to address functional vision, the large D-15, although not perfect, may be the best color vision test for assessing functional color vision in a VI population.

Patients seen in Vision Rehabilitation Clinics (VRCs) have visual impairment due to a variety of ocular conditions. Considering the severity of their ocular conditions, patients with visual impairment may have significant acquired color vision deficiencies. There are reports of color vision findings in visually impaired children who attended a VRC; however, only limited information is available about similar adult patients.[4,22] The purpose of this study was to assess moderate/severe CVD tested under standardized conditions among adults attending a VRC. The findings demonstrated the range of VI that could be tested using this methodology and the large percentage of CVD in an adult VI population. Trends related to subjective personal report of color vision, level of VI, ocular diagnosis, and presence of CVD were assessed.

Methods

Color vision (CV) was tested on adult patients attending a VRC using the 3.3 cm stimulus size 'Panel Quantitative Color Vision Test' (D-15) OD and OS (Good-Lite Company; Elgin, IL). Instructions were given to patients using standardized wording.[17] To simulate Standard Illuminant C closely, the color vision test was illuminated using the Richmond Daylight Illuminator, which has a bulb with a color temperature of 6280 Kelvin; overhead lights were turned off (Richmond Products, Albuquerque, NM).[23] Patients wore the prescription that allowed them to attain their best visual acuity and a plus lens appropriate for the test distance (16 inches).

Table 1. Vision Impairment Classification

Visual Impairment Classification	Visual Acuity
Normal/near normal	20/20 (6/6) - 20/60 (6/18)
Moderate	20/70 (6/21) - 20/160 (6/48)
Severe	20/200 (6/60) - 20/400 (6/120)
Profound	20/500 (6/150) - 20/1000 (6/300)

CV testing was attempted on each eye if patients had quantifiable vision in that eye. If patients reported that they were unable to do the testing, the test was discontinued. If the examiner felt that the patient did not understand the test, it was re-explained. If the patient still did not appear to understand/be able to complete testing, the test was discontinued.

Demographic information was recorded. Patients were surveyed for family and personal history of CVD and whether their color vision had changed throughout their life. The attending doctor (JW, TM, or KS) documented the primary cause of vision impairment and the best-corrected visual acuity OD and OS.

All D-15 tests were scored by JW using traditional methods.[17] The CV test was classified as 'fail' if there were two or more major crossover errors in either eye. If patients were classified as 'fail,' the orientation of the major crossover errors was compared to the protan, deutan, or tritan index line. If the large majority of crossover errors were parallel with one type of CVD, the patient was assessed as having that type of CVD in the eye tested. If the large majority of crossover errors were not parallel to one type of CVD, the patient was assessed as having non-specific CVD in that eye. If patients did not make two major crossover errors, they were assessed as 'pass' in that eye. If patients were assessed as 'fail' in either eye, they were classified as CVD. If patients were assessed as 'pass' in both eyes or 'pass' in one eye and the other eye could not be tested, they were classified as non-CVD.

Vision impairment (VI) was classified using central acuity and based upon ICD-9 standards (Table 1). The primary cause of VI was sub-classified into conditions primarily affecting the optic nerve, the retina, or other. Conditions classified as affecting the optic nerve included glaucoma, optic atrophy, and optic nerve hypoplasia. Conditions classified as affecting the retina included myopic degeneration, macular dystrophy, diabetic retinopathy, retinitis pigmentosa, macular degeneration, cone dystrophy, congenital stationary night blindness, retinopathy of prematurity, and hereditary retinal dystrophy. Conditions classified as other included oculocutaneous albinism, congenital nystagmus, cataract, aniridia, and aphakia.

Descriptive statistics, frequencies, and proportions were generated on demographic information, cause/level of visual impairment, personal/family history of color vision deficiency, and presence/type of color vision deficiency. Cross tabulations

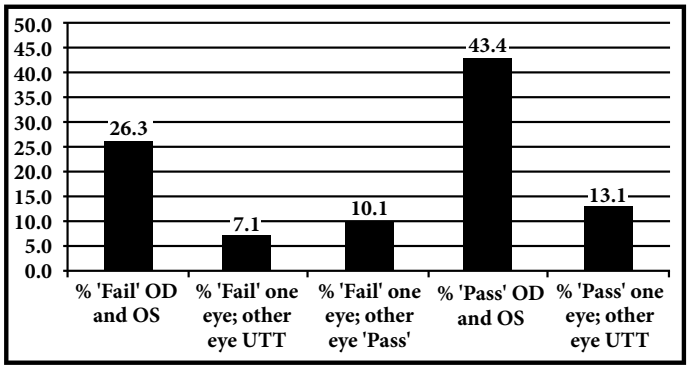

Figure 1. *Color vision (D-15) test result*

Table 2. Primary Cause of Vision Impairment for Those with Color Vision Deficiency

Ocular Condition
Glaucoma
Myopic degeneration
Optic atrophy
Macular dystrophy
Diabetic retinopathy
Retinitis pigmentosa
Macular degeneration
Cone dystrophy

All ocular conditions that have more than one color vision deficient patient are listed.

were generated to examine the association between counts of CVD and level of VI. For this analysis, those classified as 'severe impairment' and 'profound impairment' were combined into one category due to low subject number. Data was analyzed using SAS 9.2 software (SAS Institute Inc., SAS 9.1.3 Help and Documentation, Cary, NC: SAS Institute Inc., 2000-2004.) This project was approved by the Institutional Review Board of the Illinois College of Optometry. All patients consented to participation in the study. Investigations were performed according to the Declaration of Helsinki.

Results

Of the 104 patients tested, ninety-nine patients completed D-15 testing. Most patients completed testing in both eyes (80%; N=79); however, 20% (N=20) completed testing in only one eye. For those patients who completed testing, the level of VI in the better-seeing eye or only eye that completed testing was 34.3% (N=34) normal/near normal, 45.4% (N=45) moderate, 19.2% (N=19) severe, and 1% (N=1) profound. The majority of patients (61.6%; N=61) were female.

More than 40% of patients (43.4%; N=43) were classified as color vision deficient (CVD). Specifically, 33.3% (N=32) were classified as CVD in both eyes, or in one eye if the other could not be tested, and 10.1% (N=10) were CVD in one eye but not in the other (Figure 1). The majority of CVD patients identified as African-American (88.4%; N=38), while 9.3% (N=4) identified as Caucasian, and 2.3% (N=1) identified as Hispanic. The majority (55.8%; N=24) of the patients were female. The mean (SD) age was 55.0 (19.2) years. Level of VI in the better-seeing eye among those with CVD was 27.9% (N=12) normal/near normal, 41.9% (N=18) moderate impairment, 27.9% (N=12) severe impairment, and 2.3% (N=1) profound impairment. There was no statistically significant association between diagnosis of CVD and level of VI ($p>0.05$).

History of color vision issues was reported by 26.9% of patients (N=25) who completed color vision testing. When CVD classification is considered, 39% (N=16) of those classified as CVD and 17.3% (N=9) of those not classified as CVD reported a history of color vision issues. In addition, among those reporting a history of color vision issues, the large majority (84%; N=21) reported that their color vision had changed over time. This was consistent between those classified as CVD (81.2%; N=13) and non-CVD (88.9%; N=8). A family history of CVD was reported by two; one of these patients was diagnosed as CVD. Two patients who reported a personal history of CVD stated that their color vision had not changed over time and had D-15 results that demonstrated a similar CVD OD and OS. These two patients may have had a contributory congenital CVD.

The type of CVD could not be classified in either eye/only eye that could be tested in the majority of patients (69.7% N=30). Color vision deficiency was assessed as tritan in both eyes/only eye tested in 29% (N=7) and as deutan in both eyes/only eye tested in 4.6% (N=2). The remaining 9.3% (N=4) had different assessments in each eye. In 7.0% (N=3), one eye was assessed as tritan and the other was unable to classify. In 2.3% (N=1), one eye was assessed as protan and the other was unable to classify.

In those who completed color vision testing, the primary cause of VI was classified as optic nerve-related in 30.3% (N=30), retina-related in 51.5% (N=51), and other in the remaining 18.2% (N=18). Of those assessed as CVD, the primary cause of VI was assessed as optic nerve disease in 30.24% (N=13), retinal disease in 65.1% (N=28), and other ocular disease in 4.7% (N=2). No further analysis was done due to the variability of ocular conditions causing VI. The condition with the greatest number of patients being diagnosed with a CVD was glaucoma (N=6). Table 2 lists the primary cause of VI for those with CVD.

Discussion

The high percentage of CVD identified seems logical based upon the severity of ocular disease typically encountered in a VRC. This supports the importance of color vision testing in this population. Since acquired color vision defects can be difficult to classify, it is not surprising that the majority of CVD was unable to classified. Those identified with CVD have a wide variety of ocular conditions and levels of VI. Interestingly, those with and without CVD noted a personal history of CVD and a change in color vision. Color vision deficiency was not present solely in those with the most severely affected vision, or

in those who reported personal color vision issues, underscoring the importance of color vision testing regardless of the level of VI or any report of color vision issues. These findings are applicable not only to eye care professionals but also to all professionals, such as occupational therapists, rehabilitation teachers, and orientation and mobility specialists, who are participating in the patient's care.

Some patients in this study could have had a congenital color vision deficiency. However, most patients followed trends that would be consistent with acquired CVD. Few reported a family history of CVD (N=2). The majority of patients were female. Few traditional red-green color vision defects were identified. There was asymmetry in CVD between the eyes in many patients. Due to these factors, it would seem likely that most patients had acquired CVD.

Clinically, results from the D-15 can be useful in developing a color vision assessment battery. The D-15, while not a perfect predictor of issues with surface colors of CVD patients, shows trends that do allow general assumptions of color perception to be made based upon the findings.[15,19] Those who 'fail' the D-15 are likely to have some issues with color perception.[19] VRC patients who report no color vision issues but who fail D-15 testing may need additional assessments to further evaluate functional color vision perception. For example, a specific targeted questionnaire regarding color vision issues may be given to the patient.[12] In addition, a color identifier app could be used to assess the patient's perceptions of surface colors further. This may uncover issues that need to be addressed in the rehabilitation plan. For those who pass D-15 testing but who report issues with color vision (N=9 in this study), a mild CVD would be suspected. Clinically, a desaturated D-15 or other color vision test could be attempted to assess these patients further. For those with a mild CVD, modification to rehabilitation testing/training may not be needed. However, the mild CVD should be discussed with the patient in order to uncover further difficulties that the patient may be experiencing.

The study protocol was designed to demonstrate a methodology for color vision testing in a VRC using equipment readily available commercially. Due to this, a battery of color vision tests was not performed in this study. The large D-15 was chosen so that the greatest number of patients could complete the testing and so that results could be compiled for a variety of VI levels. In addition, the large D-15 is considered more applicable to functional color vision, which is essential in a VRC.[21] Although the MacBeth light most closely approximates Standard Illuminant C, which is the gold standard for D-15 testing, it is no longer available commercially. The Richmond Daylight Illuminator was chosen since it has been shown to be an acceptable substitute for the MacBeth light and is commercially available as well as portable.[23-25] The protocol used in this study could be duplicated in a VRC.

Although results cannot be generalized, similar trends would be expected to be found at other VRCs. Most of the research done to assess functional color perception has been done on normally sighted subjects. Future research is needed to assess the effect of CVD on driving, education, vocation, avocation, etc. using VI patients to determine whether findings are similar to those in non-VI individuals. The effect of CVD on the use of electronic and non-electronic optical devices, non-optical devices, and adaptive technology should also be investigated.

Conclusion

D-15 testing was completed on patients with a wide range of VI levels, demonstrating a protocol for color vision assessment in a VRC clinic. Over 40% of the VI patients were assessed with a CVD. There was a range in the level of VI and the type of ocular disease identified in those with CVD. No statistically significant relationship was found between CVD and VI level. Both patients with and without CVD reported a personal history of color vision issues and a change in their color vision. Although there is no treatment for CVD, modification of the individual rehabilitation plan and additional testing may be needed. Education about acquired CVD and specific activities that CVD may impact is essential, especially due to possible CVD progression as the ocular conditions worsen.

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