Clinically relevant colour album test for the colour defective medical student

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Purpose: To evaluate the impact of color vision deficiency (CVD) in medical undergraduates by a more clinically applicable test. **Methods:** Cross-sectional study of 31 students with CVD (Ishihara diagnosed) asked to identify subject-specific signs/tests requiring color identification on a customized medical multispecialty designed color album test (CAT). They were further subjected to Farnsworth D-15 testing. **Results:** The error score of CVD students (4 ± 3.2) on 39 plates of color album test was highly significant as compared to the error score of color normal (0.3 ± 0.6). The CAT depicted linear correlation with Farnsworth D-15 and emerged as a valid tool of assessment. Ishihara interpretation did not correlate with the clinical impact of CVD. Nature of error suggests that CVD students can anticipate problems in dermatology, pathology, hematology, microbiology, and biochemistry. **Conclusion:** Color album test is a more clinically relevant test for CVD doctors to identify specialties where they can anticipate difficulties

Key words: Color album test, color vision defective, Ishihara test

Medical students encounter various colored signs in clinical practice, such as pallor, icterus, and cyanosis. Persons with color vision deficiency (CVD) may have difficulty in assessment of these colored signs; alternatively, these signs may be missed, leading to wrong diagnosis and mismanagement of patients.[1,2]

In the context of the health profession, color vision is not always tested nor is its deficiency a bar to qualifying or certifying exam of medical graduation. The guidelines change with some countries, such as India requiring color vision screening at the time of entrance to medical college without any counseling for career guidance or job options.

The test adopted for screening CVD has traditionally been Ishihara charts, sometimes aided with Edridge–Green lantern or Martin lantern.[3,4] Those with higher grades on Edridge–Green lantern are considered eligible to pursue a medical specialization in India.[3] Farnsworth D-15 test is sometimes resorted to in those with doubtful Ishihara scores.[5]

However, for the medical profession, these guidelines extrapolated from recommendations for navigational personnel lead to a lack of contextual perspective regarding the ability of CVD doctors.

This is neither ethically nor technically correct as any screening test for *fitness to practice* should be combined with giving career advice, and timely diagnosis may permit early modifications in educational and other activities.[6]

The current need is to supplement or substitute existing color vision tools with objective, professionally contextual diagnostic tests. This would assist in the formulation of rational guidelines and ensure medical personnel with CVD adopt safe clinical practices. Our study by devising such a *specialty-based color album* sought to fill this need.

Methods

This study was a cross-sectional, observational study conducted over the period from October 2016 to March 2018.

A color album consisting of 39 colored pictures, with 2–3 pictures detailing tasks or procedures requiring color discrimination pertaining to each specialty taught during medical training was generated by seeking the help of specialty experts [Table 1]. After obtaining clearance from the institutional review board and written informed consent from the study subjects, a total of 1500 (861 men) medical students studying at our institution were screened at the beginning of this study with the 38-plate edition Ishihara chart. Farnsworth D-15 test was undertaken to classify the type of CVD into protans or deutans.

As per standard protocol, students who made three or more errors on Ishihara were considered color vision deficient; they were invited to volunteer for the study. To control for the degree of exposure to and degree of experience with laboratory and clinical work, an equal number of undergraduate students from the same batch who made no errors on Ishihara testing were invited to volunteer as *controls*. Students with CVD underwent examination to exclude ocular conditions known

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Table 1: The colour album test (CAT)

Speciality	Photographs included (Photograph number)
Anatomy	Spleen histology (Photograph no. 1), Thymus gland histology (Photograph no. 2)
Biochemistry	Benedict test (Photograph no. 3), Seliwanoff test (Photograph no. 4)
Physiology	Blood grouping (Photograph no. 5), Peripheral blood smear (Photograph no. 6)
Microbiology	Blood agar (hemolysis) (Photograph no. 7), MacConkey agar (lactose fermentation) (Photograph no. 8)
Pathology	Ziehl-Neelsen (Acid fast) staining (Photograph no. 9), Skin immunofluorescence (Photograph no. 10)
Pharmacology	Amaranth dye/calamine lotion (Photograph no. 11)
Forensic medicine	Bruise (age by color) (Photograph no. 12), Abrasion (old vs. new) (Photograph no. 13), Autopsy liver (normal vs. fatty) (Photograph no. 14)
Preventive and social medicine	Vaccine Vial monitor (Photograph no. 15), Biowaste management (Photograph no. 16), Traffic signals (Photograph no. 17)
Ophthalmology	Worth 4 dot test and Duochrome test (Photograph no. 18), K-F ring (Photograph no. 19) Fundus (normal/pallor/cupping) (Photograph no. 20)
Otorhinolaryngology	Acute pharyngitis (Photograph no. 21), Acute otitis media (Photograph no. 22) Tongue sores (Photograph no. 23)
Medicine	Dengue rash (Photograph no. 24), Cellulitis (lower limb) (Photograph no. 25)
Surgery	Melena (Photograph no. 26), Lymphangitis (Photograph no. 27)
Obstetrics and Gynecology	Pallor (conjunctiva) (Photograph no. 28), Chadwick Sign (Photograph no. 29) Peripheral cyanosis (Photograph no. 30)
Pediatrics	Jaundice (Photograph no. 31), Fever with Rash (Photograph no. 32)
Dermatology	Erythema Multiforme-Target sign (Photograph no. 33), Tinea (Photograph no. 34) Miliaria (Photograph no. 35)
Anesthesia	I.V. Cannula (Photograph no. 36), Oropharyngeal Airways (Photograph no. 37)
Orthopedics	Gout-Podagra (Photograph no. 38), Felon (Photograph no. 39)

to cause acquired color vision deficiency (chorioretinal or optic nerve disease). The names, identities, and clinical data of students with CVD were kept confidential.

Students with CVD as well as controls were asked to independently (albeit in the presence of one of the authors) interpret the color-dependent clinical and laboratory photographs. Total error score (TES) for each task was noted.

When the proportion of students with CVD and color normals who made the error was the same, for both groups, the error was considered not to be related to CVD. However, when considerably more students with CVD made errors than controls from the same batch, we assumed that the errors were related to the CVD.

The Chi-square test was used to compare the proportion of cases and controls who made errors in assessing the individual colored clinical photographs. The quantitative variables in both groups were expressed as mean ± SD and compared using unpaired t test between groups.

Pearson correlation was used to determine the relationship between errors on the Ishihara test and Farnsworth D-15 test, errors on Ishihara and errors on the color album, error score on D-15, and errors on the color album.

Comparison of errors among the CVD groups was done using Mann–Whitney U test and Kruskal–Wallis test. SPSS version 17 was used for statistical analysis.

Results

Of the 1500 students screened (Ishihara chart); 42 (4.9%), all men, were found to have CVD. Of these, only 31 consented

to participate in the study, and an equal number of controls were enrolled. Most students with CVD (28/31; 90.3%) reported that they were first diagnosed to be color vision deficient after admission to the medical course.

While students with CVD misread 08–30 slides on Ishihara testing (mean [SD]: 22.5 [5.5]), controls made no errors. Students with CVD made 0–10 errors in 39 color-dependent photographs (mean [SD]: 4.06 [3.20]), whereas color-normal students made 0–3 errors (mean [SD] 0.29 [0.58]; $P < 0.00$).

To validate the new CA test, a correlation was done between errors made on Ishihara and those on the color album. A significant positive correlation was found with a Pearson correlation value of 0.55 ($P = 0.001$). The CA test was further validated by correlation D-15 error score. This also showed a positive correlation with a Pearson correlation value of 0.779 ($P = 0.000$).

Severe CVD subjects made significantly more errors with deuteranopes making more mistakes than deuteranamalous subjects at 28: 22 (Ishihara), 39:25 (on D 15), and 15.6:2.4 (on color album). On comparing *protans* (protanopia) versus *deutans* (deuteranopia + deuteranomaly), more errors were done by *protans* on all three testing tools (Ishihara, D 15, and CA test). However, statistical significance was seen only on the CA test at $P = 0.04$ (Mann–Whitney U test). Deuteranomaly was the most common CVD detected at 61.3% followed by Duteranopia at 19.4%.

Students were asked to fill a questionnaire regarding their expectations and reservations about their medical career with their handicap. Quantitative analysis revealed a specific request for career counseling by 81% of students,

with the preferred time being during under-graduation by 55%. During such career advice 58.0% wanted detailed advice regarding selection of branch for post-graduation. All wanted to know about the adaptive strategies or help available to cope with CVD. Approximately 58% perceived that screening done with Ishihara did not truly reflect the difficulties faced by them in their subjects and they conclusively agreed CA to be a more valid method in synchronous with their daily task.

Discussion

The prevalence of CVD in our students, at 4.87% among the male population, was lower than that reported from the general population (6%–8%).[7,8] The reason could be that our sample was from a limited institutional population.

On objective testing, students with CVD as well as those who were color normal made errors in the interpretation of colored signs. Maximal errors occurred in seeing shades of *red* during hematology (blood grouping and peripheral blood smear), Ziehl–Neelsen stain, in diagnosing melena, and in interpreting skin signs of lymphangitis, tinea, or miliaria. In addition, *red-blue* differentiation in skin signs for the age of bruise, peripheral cyanosis, and *green* differentiation on identifying hemolysis on blood agar were the other problematic areas. Minimal errors occurred in interpreting mucous membrane signs, namely conjunctival pallor, Chadwick sign, pharyngitis, and otitis media, which involved the differentiation of shades of red and blue. Stereoscopic clues were a big help in reducing errors due to CVD.

The following is a detailed discussion on clinical situations where color clues assume significance [Table 2 and Fig. 1].

(**A**) **Photographs depicting peripheral blood smear and blood identification**

In these situations, CVD subjects made the most errors.

Ziehl–Neelsen's staining of acid-fast bacilli recorded an interesting finding of most CVD students correctly identifying and counting the number of acid-fast bacilli; however, they confessed that they did not perceive them as red. Of these students, deutans faced the maximum difficulty in interpreting such slides correctly. The same finding has been corroborated by a study on 270 male histopathologists and medical practitioners.[2,9] However, researchers have opined that CVD does not impact the work in pathology as much, due to its primary reliance on cell morphology and arrangement.[10] The use of a magenta filter is of some benefit in those aware of their CVD while performing the histology work.[11]

(**B**) **Skin signs** were especially difficult to be analyzed by CVD subjects viz. age of bruise, lymphangitis, peripheral cyanosis, tinea, and miliaria. For peripheral cyanosis and tinea identification, CVD subjects identified the abnormality with color perception differing, for them it was pink and green, respectively. In the skin slide depicting dengue rash, a protanope identified the pathology correctly but saw it as green. However, a deutan failed to identify it.

(**C**) **Mucous membrane signs** were also perceived to be difficult to be analyzed by CVD subjects, with conjunctival pallor detection having maximum difficulty. For interpreting acute pharyngitis or Chadwick sign of pregnancy, very few CVD students (<3) made errors. Difficulty in the perception of conjunctival pallor and mucous membrane inflammation signs has been concurred by prior researchers.[1,12,13]

For acute otitis media, most subjects could correctly identify the abnormality; the reason for the same could be the inherent presence of stereoscopic clues in the picture. This concurs with previous studies showing that a CVD person does not face much difficulty in otoscopic examinations.[1,9,12]

(**D**) **Body fluids:** Malena picture resulted in CVD subjects making significantly more errors than color-normals in

Table 2: Mistakes on photographs

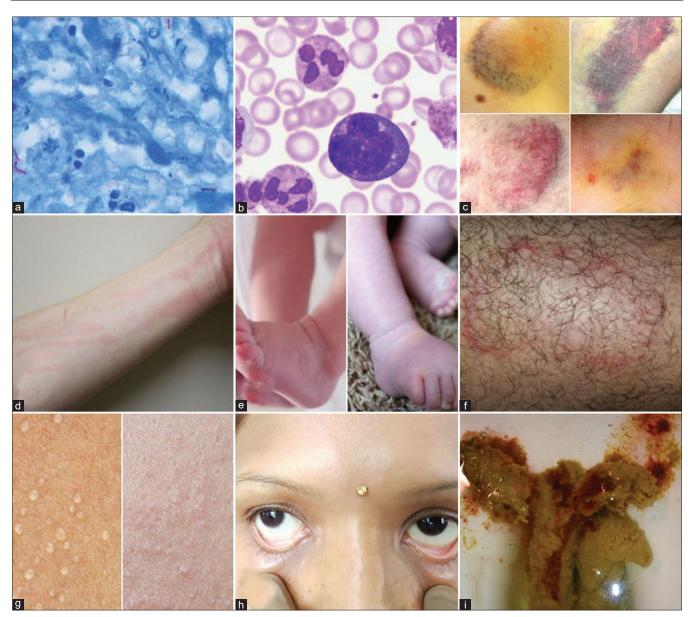| Pictures on which moderate errors were made (≥4)		Pictures on which mild errors were made (up to 3)		Pictures on which mistakes were nil	
Picture no.	Title	Picture no.	Title	Picture no.	Title
5	Blood grouping	3	Benedict test	1	Spleen histology
6	Peripheral blood smear	4	Seliwanoff test	2	Thymus histology
7	Hemolysis on blood agar	14	Autopsy Liver	8	MacConkey agar
9	Zn staining	18	Worth 4 dot/Duochrome test	10	Skin Immunofluorescence
10	Age of bruise	21	Acute Pharyngitis	11	Amaranth dye/Calamine lotion
12	Blood in stools	22	Acute Otitis media	13	Abrasion
27	Lymphangitis	24	Dengue rash	15	Vaccine Vail monitor
28	Conjunctival pallor	25	Cellulitis	16	Biomedical waste management
30	Peripheral cyanosis	29	Chadwick sign	17	Traffic signals
34	Tinea	31	Jaundice	19	KF ring
35	Milliaria			20	Fundus (normal/pallor/cupping)
38	Gout (podagra)			23	Tongue Ulcers
39	Felon			32	Fever with rash
				33	EM target sign
				36	IV cannula
				37	Oropharyngeal airway

Figure 1: Pictures on which moderate errors were made (4 or more): (a) ZN staining; (b) Peripheral blood smear; (c) Age of bruise; (d) Lymphangitis; (e) Peripheral cyanosis; (f) Tinea; (g) Miliaria; (h) Conjunctival pallor; (i) Melena

describing the abnormality. Some of the students could locate the abnormality but reported it to be appearing as green. This finding is consistent with Reiss *et al.*,[14] who on studying the impact of color blindness on recognition of blood in body fluids found that the lowest rate of correct identifications occurred with pictures of stool and which correlated with the severity of CVD. Anecdotal report by a deutan general practitioner "*I once diagnosed a hematemesis as bile, the patient was lucky to survive*" shows the extent of errors this can give rise to.

(E) Ophthalmological signs: Most CVD subjects were correctly able to identify and describe the abnormality in most of the photographs, namely KF ring, fundus-normal/disc, and pallor/glaucomatous disc. Only in the duochrome test and Worth 4 dot test did the students make a significant error with deuteranopes having more confusion. This is in variance to the report of a red-blind physician facing significant difficulties in ophthalmological signs.[15] Contrast differences between

pigmented and surrounding nonpigmented areas have been used by CVD optometrists to assist in defining abnormal areas.[16]

(F) Colorimetric tests: Most CVD subjects were able to identify and describe abnormality, with only one student each of protanope and deuteranope making an error in Benedict and Seliwanoff test, respectively.

(G) The clinical situations in which subjects made no errors dealt with the following subjects: anatomy (spleen histology and thymus histology), pharmacology (amaranth dye/calamine lotion), preventive and social medicine (vaccine vail monitor, biowaste management, and traffic signals), and anesthesia (IV cannulas and oropharyngeal airway). These color tests can be stated color neutral, with students relying on knowledge and understanding to give the correct answer.

Concerning colorimetry, studies have shown that with the chromaticity of charts currently in use, no problem arises in

detecting the presence or absence of glucose, and errors if any may occur only during quantitative testing.[17] Safe clinical practices suggested while interpreting colored clinical signs included cues such as contrast, borders, surface, stereopsis use of adequate lighting, reliance on a detailed history, help of seniors, and employing noncolor dependent digital technology.

Implication and limitations

Our study confirmed that CVD medical students encounter significant problems in identifying color-cued diagnoses. Fields of dermatology, pathology, hematology, microbiology, and biochemistry could be challenging for such students. For clinical subjects such as pediatrics, medicine, and ophthalmology where color changes in skin, conjunctiva, and fundus are important indicators of disease, specific training needs to be imparted in the use of additional adaptive strategies.

The limitations of our study were the use of study photographs of color-dependent signs instead of real clinical situations. All tests were done under standard illumination, while such good illumination may not be present in real-life situations. Detailed history on ancillary clues was not provided; most studies state additional clues gleaned from a careful history aid in diagnosis.

The use of additional cues is probably inherent to persons with CVD even if they are not aware of the CVD. However, students un-aware of the problem may not ask for help and instead doubt their learning ability. Timely detection along with counseling can aid students to adopt safe clinical practices and dictate informed career choices about post-graduation specialty.

Conclusion

In the Indian context with CVD students debarred from pursuing the profession or from training in a specialty of choice, it is unethical to base this on noncontextual tests like Ishihara. A more clinically applicable test, like the CAT, should be resorted to.

Timely awareness and targeted counseling followed by practicing adaptive strategies to ensure patient safety can make these doctors enter mainstream jobs without guilt or fear. Our policies concerning the recruitment of medical professionals with CVD need to be overhauled and made realistic.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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