Beyond photography: Evaluation of the consumer digital camera to identify strabismus and anisometropia by analyzing the Bruckner's reflex

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Amblyopia screening is often either costly or laborious. We evaluated the Canon Powershot TX1 (CPTX1) digital camera as an efficient screener for amblyogenic risk factors (ARF). We included 138 subjects: 84-amblyopes and 54-normal. With the red-eye-reduction feature off, we obtained Bruckner reflex photographs of different sized crescents which suggested anisometropia, while asymmetrical brightness indicated strabismus; symmetry implied normalcy. Eight sets of randomly arranged 138 photographs were made. After training, 8 personnel, marked each as normal or abnormal. Of the 84 amblyopes, 42 were strabismus alone (SA), 36 had anisometropia alone (AA) while six were mixed amblyopes (MA). Overall mean sensitivity for amblyopes was 0.86 (95% CI: 0.83-0.89) and specificity 0.85 (95% CI: 0.77-0.93). Sub-group analyses on SA, AA and MA returned sensitivities of 0.86, 0.89 and 0.69, while specificities were 0.85 for all three. Overall Cohen's Kappa was 0.66 (95% CI: 0.62-0.71). The CPTX1 appears to be a feasible option to screen for ARF, although results need to be validated on appropriate age groups.

Key words: Amblyopia, anisometropia, digital camera, photoscreening, strabismus

Introduction

Amblyopia is mainly due to childhood strabismus and anisometropia,[1] and risks the possibility of bilateral impairment if trauma or adult eye conditions impact the better eye,[2] It is often preventable or reversible with appropriate timely interventions,[3] and thus remains a focus of screening. High end photo-screeners are not in widespread use due to costs, while simpler techniques are time consuming, labor intensive and require efficiency.[4]

Any useful screening test should be simple, safe, precise, acceptable, affordable, portable and efficient. Such advantages accrue by utilizing the Bruckner's reflex, with the retinoscope and the consumer digital cameras (CDC).[5-8] The enhanced Bruckner reflex, visible from the top or side of the ophthalmoscope,[9] generates a light crescent in the pupil of an ametropic eye, while an uniformly brighter reflex is seen from the strabismic eye. The child friendly CDC records this, permitting both anisometropia and strabismus to be identified.

We used the Canon Powershot-TX1 (CP-TX1), as recommended by the lead author of the Alaskan study[8] (personal communication) [Fig. 1], to assess its capability in identifying amblyogenic risk factors (ARF), namely strabismus and anisometropia, by evaluating its performance on a co-operative clinic population of amblyopes and normals.

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Materials and Methods

After Institutional Review Board (IRB) approval, and informed consent, we included amblyopes with good bilateral red reflexes on ophthalmoscopy and excluded those who were too young to cooperate, unwilling to participate and pseudophakes. Amblyopes were patients having either anisometropia or strabismus, with a difference in best corrected visual acuity (BCVA) of ≥ 2 lines-Snellen, and no other organic pathology. Pre-cycloplegia, they were photographed from five feet, seated on a chair, in primary gaze, in a dim room (rheostat controlled, such that newsprint could be read with difficulty). With the aid of the 10 × optical zoom, flash photographs with bilateral red reflexes were recorded.

In addition, normal controls, without significant ametropia, having 20/20 Snellen Visual acuity (VA), and either orthotropia or mild-moderate phoria, demonstrating good recovery on cover test, and stereopsis of <100 arc seconds, were also similarly photographed. After a detailed work up, patients were grouped as: Strabismic-alone amblyopes (SA: without any significant anisometropia (<0.5 D), Anisometropic-alone amblyopes (AA: Anisometropia ≥0.5 D, and no strabismus) and Mixed amblyopes (MA: Having both strabismus and anisometropia).

The photographs were transferred to a laptop, cropped and coded. Eight compact discs (CDs) were made, with randomly arranged photographs. A separate instructional CD of 12 photographs, four each of controls, strabismics and anisometropes, helped train the raters: 'Normal' response if bilaterally the red glow appeared uniform and symmetrical [Fig. 2a]. All others were 'abnormal' [Fig. 2 b-d]; whether hyperopic (visible superior crescents), or myopic (visible inferior crescents); a difference in inter-ocular brightness suggested strabismus.

Eight medical, paramedical personnel, randomly selected from the department analyzed the CDs after the instructional CD had been repeatedly presented, altering the order till they correctly categorized at least 10 of the 12 snaps.

Statistical Analyses

We used Statistical Package for the Social Sciences (SPSS) (V-12) and JavaStat to calculate diagnostic indices (95% CI) and compared inter-rater agreement with Cohen's Kappa.

Results

We included photographs of 138 subjects, 85 (61%) males;

Figure 1: The Canon Powershot TX1 (CP-TX1) digital camera used in the study

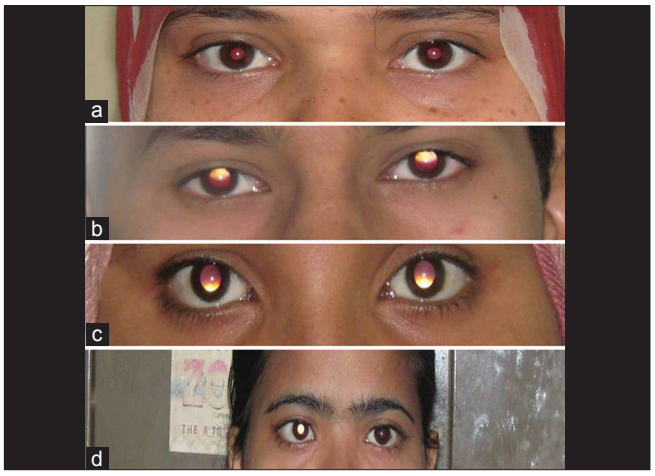

Figure 2: (a) Symmetrical red glow of both eyes suggestive of straight eyed emmetropia (normal). (b) Upper crescents, larger in the left eye: interpretation is anisometropia (hyperopic): Actual refraction: RE: +3 D + 0.5 DC × 180, LE: +4.5 D + 0.5 DC × 180. (c) Inferior crescents, larger in the left eye: interpretation is anisometropia (myopic): RE: -3.0 D; LE: -4.5 D. (d) Brighter red reflex in the right eye, indicative of an ocular deviation; suggests a strabismus (RET 30 PD)

baseline characteristics are shown in Table 1. There were 48 amblyopes with strabismus: 42 SA, and 6 MA, of these 48, 24 (50%) had esotropia (ET), 23 (48%) had exotropia (XT) and one, a vertical tropia. Mean (SD) strabismus at distance was 40.71 (22.54) prism diopter (PD) and at near 41.67 (22.26) PD. There were 36 AA; 22 (61.1%) had anisometropia between 1-2 D, and 14 had >2 D. For analyses, the amblyopes were re-categorized into six groups [Table 2] and compared with normals (n = 54). The summary of diagnostic indices (95% CI) of the raters and Cohen's kappa were calculated.

Discussion

Our study using the CP-TX1, even with subgroup analyses, returned diagnostic indices around 80% [Table 2]. It is important to remember that most of the studies evaluating/screening either amblyogenic conditions or refractive errors have been done on younger and more appropriate age groups; while we had set out to evaluate the performance of the CDC to detect strabismus and anisometropia *per se*: Appropriate age group analyses would be planned subsequently if this analyses yielded encouraging results.

Despite extensive literature, studies differ widely with respect to the personnel performing screening, age when screened, tests utilized and the referral criteria, thus making comparisons challenging.

With VA tests, a study has shown significant better performance (P=0.0001) of the Glasgow Acuity Cards (sensitivity 100%) compared to Sherridan Gardiner test (sensitivity 74%),[10] while another using the latter yielded high negative predictive value (NPV) (99-100%).[11] Lea Symbols and HOTV have produced amblyopia detection sensitivities of 0.65 (95% CI: 0.54-0.76) and 0.52 (95%CI: 0.42-0.63) with specificity fixed at (SFA) 94%.[12,13]

Cover test for detecting strabismus returned sensitivity of 75% (95%CI: 57.7-89.9) and specificity of 100%.[14] With SFA 94%, the cover-uncover test yielded a sensitivity of 27% (95%CI: 17-37).[13]

The Polaroid suppression test (PST) to detect amblyopia yielded sensitivity of 96.2%, specificity of 41.1%,[15] and is thus no longer being used in the UK. The Worth 4-dot test has returned sensitivity of 91.6% and specificity of 96.3%.[16]

The Random dot E (RDE) stereo-test scored sensitivity of 54% and specificity of 87% when tested on children referred due to a one-line difference on VA testing.[17] The VIP Study group reported sensitivities of RDE and Stereo Smile as 0.63 and 0.77 for amblyopia with SFA 90%, and lower values of 0.28 and 0.61 respectively, with SFA 94%,[13] and sensitivities of non cycloplegic retinoscopy (NCR) for amblyopia as 0.85 (SFA 90%) and 0.88 (SFA 94%).[12,13]

A study using the Otago photo-screener for ARF found a sensitivity of 81% and specificity of 98%.[18] Ottar, using the Medical Technology and Innovation (MTI) photo-screener reported sensitivity of 81.8% and specificity of 90.6%, while stating that it detected all cases of strabismus.[19] On the same data- set, Donahue *et al.* reported the sensitivity for detecting anisometropia, as low as 46% for +1.25 D, subsequently improving to 48% for + 1.5 D, 81% for +2.0 D and 100% for ≥2.5 D.[20] Hatch's study yielded lower sensitivities (54% and 53%: Due to differing referral criteria) and specificities (87% and 91%) with the MTI photo-screener.[21] Barry and Konig used the Retinomax NCR to screen for amblyogenic anisometropia and reported sensitivity and specificity of 80% and 58% for >1.5 DC or > 1 D anisometropia, and 70% and 60% for 2.0 DC or 1.5 D anisometropia.[22] The vision in preschoolers (VIP) Study group using the Retinomax reported a sensitivity of 85% (SFA 90%) and 77% (95%CI: 67-87) with SFA 94%.[13] In addition the VIP Study group also provided sensitivities for amblyopia screening of 80% and 57% (95% CI: 47-67) for Power Refractor, 62% and 62% (95% CI: 52-72) for IScreen Photo-screener and 89% and 80% (95% CI: 72-88) for Sure Sight Vision Screener with SFA 90% and 94% respectively.[12,13]

On comparison with the Brückner test performed by pediatric residents, our data compares favorably: Our sensitivity of 86% vs 61% for pediatric residents, and specificity of 85% vs 71%.[19] Our figures are comparable to those of

Table 1: Descriptive characteristics (mean (SD) and median (range)) of all the subjects (*n*=138): amblyopes (*n*=84) and normals (*n*=54)

	Normal (*n*=54)	Strabismic amblyopes (*n*=42)	Anisometro-pic amblyopes (*n*=36)	Mixed Amblyopes (*n*=6)	Total (*n*=138)
Age in years					
μ (SD) age	25.0 (6.7)	18.5 (9.8)	22.5 (7.9)	18.5 (7.69)	22.1 (8.52)
Median	24 (15-50)	16.0 (2-45)	22 (5-45)	21.5 (4-24)	22.0 (2-50)
BCVA* RE					
μ(SD)	0.0 (0.00)	0.34 (0.36)	0.18 (0.17)	0.33 (0.37)	0.18 (0.28)
Median	0.0 (0.0-0.0)	0.25 (0.0-1.0)	0.2 (0.0-0.6)	0.2 (0.0-0.8)	0.0 (0.0-1.0)
BCVA LE					
μ(SD)	0.0 (0.0)	0.27 (0.31)	0.28 (0.30)	0.5 (0.37)	0.17 (0.27)
Median	0.0 (0.0-0.0)	0.2 (0.0-1.0)	0.20 (0.0-1.0)	0.5 (0.0-1.0)	0.0 (0.0-1.0)
SE† RE					
μ(±SD)	0.0 (0.0)	0.61.47)	0.06 (2.53)	−1.13 (3.37)	0.16 (1.7)
Median	0.0 (0.0-0.0)	0.0 (−1.75 to 7.0)	0.0 (−4.75 to 5.5)	-0.38 (−7.0 to 2.5)	0.00 (−7.0 to 7.0)
SE LE					
μ(±SD)	0.0 (0.0)	0.61 (1.47)	−0.69 (3.45)	-0.58 (2.87)	-0.02 (2.06)
Median (range)	0.0 (0.0 to 0.0)	0.0 (-1.75 to 7.0)	0.0 (−7.5 to 5.25)	0.13 (−6.0 to. 75)	0.0 (−7.5 to 7.0)

*BCVA: Best corrected visual acuity in logMAR, †SE: Spherical equivalent in diopters

Table 2: Summary statistics of diagnostic indices: mean (95% CI) values of eight raters, analyzed group wise (see text) Vs normals (*n*=54)

	Group 1 (*n*=84) (all amblyopes)	Group 2 (*n*=42) strabismic amblyopes	Group 3 (*n*=36) anisometropic amblyopes	Group 4 (*n*=22) 1D< anisometropia ≤2D	Group 5 (*n*=14) anisometropia >2D	Group 6 (*n*=6) mixed amblyopes
Sensitivity	0.86 (0.83-0.89)	0.89 (0.83-0.94)	0.86 (0.83-0.89)	0.77 (0.70-0.84)	0.78 (0.68-0.88)	0.69 (0.62-0.76)
Specificity	0.85 (0.77-0.93)	0.85 (0.77-0.93)	0.85 (0.77-0.93)	0.85 (0.76-0.94)	0.85 (0.77-0.93)	0.85 (0.77-0.93)
Positive predictive	0.90	0.83	0.80	0.70	0.60	0.39
Value (PPV)	(0.86-0.94)	(0.76-0.90)	(0.73-0.87)	(0.59-0.82)	(0.49-0.72)	(0.27-0.51)
Negative predictive	0.79	0.91	0.90	0.90	0.94	0.96 (0.95-0.97)
Value (NPV)	(0.75-0.83)	(0.87-0.95)	(0.88-0.92)	(0.88-0.93)	(0.91-0.97)	
Positive likelihood	8.81	9.06	8.76	7.93	8.11	7.28
Ratio (PR+)	(3.95-13.67)	(4.05-14.07)	(3.97-13.55)	(2.55-13.31)	(3.37-12.85)	(2.7-11.85)
Negative likelihood	0.18	0.14	0.18	0.27	0.27	0.38
Ratio (LR-)	(0.13-0.23)	(0.07-0.22)	(0.14-0.22)	(0.19-0.35)	(0.15-0.38)	(0.27-0.49)
Accuracy	0.86 (0.82-0.90)	0.89 (0.83-0.94)	0.85 (0.80-0.90)	0.83 (0.76-0.89)	0.83 (0.77-0.90)	0.83 (0.76-0.90)
Cohen's kappa	0.66 (0.62-0.71)	0.70 (0.64-0.75)	0.64 (0.50-0.68)	0.55 (0.50-0.60)	0.54 (0.49-0.59)	0.46 (0.40-0.53)

NPV: Negative predictive value

Kothari to detect ARF with the Brückner test: Our sensitivity of 86% vs. 87.5% and specificity of 85% Vs. 84.1%.[7] Amitava evaluating the modified Brückner test (MBT) using the streak retinoscope,[5] (on children who failed 6/9 Snellen) has reported the sensitivity and specificity as follows: 57% and 97% for anisometropia of 0.5 D; 74% and 95% for anisometropia of 1 D, and 50% and 98% for strabismus and concluded that MBT is accurate and useful for ruling them. Considering the high specificity obtained in our study, it is likely that the CDC method is equally effective.

Importantly, our study appears to have a good inter-rater agreement evident from a 66% (95% CI: 61 to 70) Cohen's Kappa statistic right across sub-groups and raters [Table 2].[23]

Conclusion

Our study provides evidence with a suitable CDC, one may effectively screen for ARFs, even if it needs validation in appropriate age groups. In all likelihood, results should be similar since sensitivity and specificity are test related characteristics and do not alter with prevalence. CDCs offer an attractive alternative for amblyopia screening, with a universal applicability appropriate in a vast developing country like ours.

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