Original Article

Smartphone photography for screening amblyogenic conditions in children

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Purpose: To validate the smartphone photography as a screening tool for amblyogenic conditions in children. **Methods:** Children between 5 to 8 years attending eye out patient department (OPD) were photographed (by an optometrist) with a smartphone to capture their pupillary red reflexes followed by clinical examination by the principal investigator (PI). The PI on the basis of clinical examination identified children with significant amblyogenic conditions and, subsequently, two ophthalmologists independently categorized the photographs on the basis of color, symmetry, and shape of the pupillary reflex into normal or abnormal. The identification of amblyogenic conditions on clinical examination was compared to that on photography. Refractive errors <3D and anisometropia <2D were excluded. Sensitivity, specificity, positive predictive value, and negative predictive value of smartphone photography screening were determined. **Results:** In all, 250 children were screened. Clinically 23.6% were harboring amblyogenic conditions. The mean sensitivity and specificity of screening by smartphone were 94% and 91%, respectively. **Conclusion:** Smartphone photography is a reliable tool for detection of amblyogenic conditions in children.

Key words: Amblyopia, smartphone photography, vision screening

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A good screening test should be inexpensive, easy to administer, not harmful, and reliable.[1] Several photographic techniques have been tried for screening of amblyogenic factors since 1979.[2] They work on the principle of Bruckner test frequently used for amblyopia screening in developing countries.[3,4] In recent times, photo screening has gained attention as a method for large-scale vision screening. However, need for special equipment and recurring costs limit its utility in the developing world.[5]

This study attempts to use the smartphone photography as a screening tool for amblyogenic conditions in children. With smartphone's widespread use, photographs can easily be obtained even in the most remote areas without any need for additional resource or skill. Screening done with photographs will be more objective and less time consuming compared to vision screening in children. These photographs can even be archived and help in creating lasting records. Furthermore, these digital photographs can be analyzed by an expert available far from the screening area and, thus, overcome geographic and economical barriers in providing medical care especially in developing countries. With many potential benefits, screening done with smartphone photographs may well prove to be a promising alternative.

Methods

Considering the obvious already discussed advantages of smartphone photography as a screening modality in children, we conducted a pilot study prior to this study to compare the inter- and intraobserver variability by presenting the same set of 50 photographs (of normal children and those with conditions altering the pupillary light reflex) for analysis to the same ophthalmologists (as in this study) in random sequences where each photograph appeared twice. The interrater agreement (kappa value) was 0.61, which showed substantial agreement. Prior to the pilot study, 20 photographs (10 normal and 10 abnormal) were together viewed and analyzed by two ophthalmologists on Windows Photo viewer on a 15" LED screen to lay down criteria for normal reflex. Images were magnified when in doubt. Well centered, round, homogenous, reddish, symmetrical glow with a horizontal diameter of half to one-fourth of corneal diameter was considered normal. Any deviation from this was considered abnormal. After the pilot study, errors in its observations were analyzed with aim to minimize them in future. Main limitations of the pilot study being OPD-based sample without predefined age.

This prospective cross-sectional study was designed to validate the utility of smartphone in detecting amblyogenic conditions. It was conducted after institutional ethical committee approval (Ref Code: 89th E.C.M.IIB Thesis/P5) in children attending the eye OPD for the first time with an ocular complaint. 250 consecutive children aged between 5 to 8 years with consenting parents were recruited after informed written consent.

Sample size calculation: Reviewing our records, the prevalence of the moderate-to-high refractive errors, anisometropia, strabismus, developmental cataract, and corneal opacities in the target population was estimated at a minimum

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of 20%. A higher frequency of these conditions in our patients could be attributed to ours being a tertiary care referral center for pediatric patients. The confidence level of 95% was agreed to be acceptable ($z = 1.96$, $P = 0.2$, and $d = 0.05$). The sample size was calculated to be 245 by the formula $n = z^2 P(1\text{-}P)/d^2$. We recruited a total of 250 children considering the possibility of few photographs being ineligible for analysis due to the lack of clarity. An agreement of 80% between photographs and clinical diagnosis was considered as limit for noninferiority of photography over clinical examination in detecting the above conditions.

Technique of photography: Photography was done in a moderately illuminated room to have a mesopic pupil size of about 6.5 mm. Subject was made to sit at 1-m distance at same level as the technician with both eyes fixing at the phone camera. Photograph was taken with a smartphone (OPPO A37f) with camera specification of 8MP rear camera with pixel density of 293 pixels per inch, with a resolution of 720 × 1280 pixels and color reproduction 16M with a f/2.4 aperture and LED flash (switched on). Centre of the flash was 4 mm away from the center of the camera. The photograph was repeated if the child moved, closed eyes, assumed a head posture (head tilt, face turn, and chin position were specifically checked), or the image captured was blurred. An average of two attempts was required each time. Fixing at a distant object could potentially relax the accommodative effort but when the subject did so the clarity of the red reflex was lost. Hence, we kept the camera as the point of fixation.

This was followed by clinical examination by the PI ophthalmologist to categorize the children into normal or abnormal based on refraction and ocular findings. Ocular surface diseases, refractive errors ≤ 3D and anisometropia ≤ 2D were considered as normal.

The methodology is explained in Flowcharts 1 and 2.

Statistical analysis

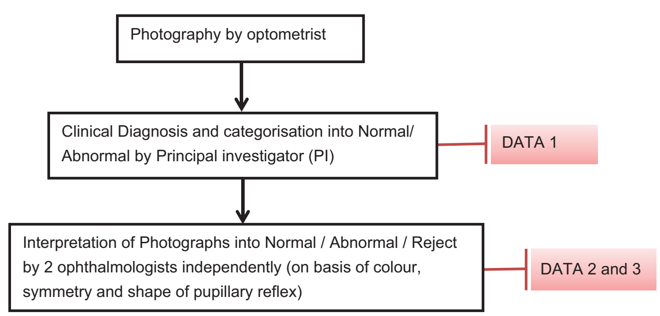
Categorical variables were presented in number and percentage. Categorical variables were compared using chi-square test/Fischer's exact test as appropriate. The data were entered in MS EXCEL spreadsheet and analysis was done using statistical package for social sciences (SPSS) version 16.0.

Results

Mean age of the patients was 6.08 ±1.11 years. None of the photographs were rejected for analysis. The PI categorized 59 (23.6%) subjects as abnormal. These were considered the "gold standard values" against which the test (photograph analysis) was validated. Ophthalmologist 1 and 2 considered 73 (29.2%) and 72 (28.8%) of photographs as abnormal, respectively. The agreement between PI and ophthalmologist 1 was 83.2% and between PI and ophthalmologist 2 was 87.1%. The level of significance was <0.001 in both. The results are summarized in Tables 1 and 2. Among the clinically positive 59 patients, 32 had bilateral (including 8 with anisometropia and 7 with strabismus) and 17 had unilateral disease. Fig. 1 shows photographs in different conditions. The interrater agreement (kappa value) between ophthalmologist 1 and 2 was 0.928, which shows near perfect agreement.[6]

Discussion

Our study focuses on reliability of smartphone photography as a screening test for significant visual morbidity in children. This is the first Indian study done to evaluate the utility of smartphone photographs as screening modality for amblyogenic conditions in children (Pubmed search). Digital camera has been used in the past but the universal availability of smartphones makes it more relevant.[7] Studies done in past using photoscreeners demonstrated a sensitivity and specificity ranging from 37% to 94% and from 40% to 90%, respectively.[8-10] This wide range in sensitivity and specificity makes these photoscreeners unreliable as screening tools. In contradiction to these results, our study demonstrated a high mean sensitivity (94%) and specificity (91%) in detecting the presence of visual morbidity. Agreement between clinical and photograph analysis was about 85%. Additionally, a high level of agreement between ophthalmologists in our study further points to the reliability of the smartphone photo analysis as the screening test. This high yield and agreement in our study could be due to a pilot study done by the same team of

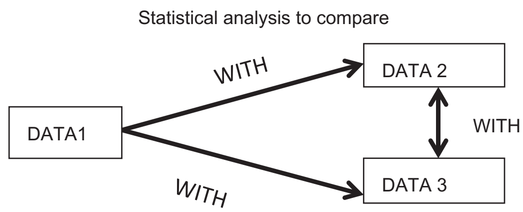


Flowchart 1: Study methodology

Table 1: Summary of results

Gold standard ↓	Test →	Ophthalmologist 1		Ophthalmologist 2	
		+ (*n*=73)	− (*n*=177)	+ (*n*=72)	− (*n*=178)
+ (*n*=59)		55	4	56	3
− (*n*=191)		18	173	16	175
Total (*n*=250)					
	Sensitivity	93.2%		94.9%	
	Specificity	90.5%		91.6%	
	Positive predictive value	75.3%		77.7%	
	Negative predictive value	97.7%		98.3%	

Legend: "+" = positive for amblyogenic conditions or abnormal, "-"= negative for amblyogenic conditions or normal



Flowchart 2: Data comparison

Table 2: Details of gold standard "positive" (+) patients

Condition	Number of patients
Hypermetropia 3.25 - 5.00	6
Hypermetropia >5.00	5
Myopia 3.25 - 5.00	4
Myopia >5.00	7
Anisometropia >2.00	8
Trauma (cataract/corneal injury)	7
Developmental cataract	4
Strabismus	7
Corneal opacity	8
Retinal detachment	1
Uveitis (miotic pupil)	1
Retinoblastoma	1
Total	59

investigators in the past. Standard guidelines were formalized to categorize the Bruckner reflexes as normal or abnormal and same were applied in this study too. It would be interesting to do a comparative study with the photoscreener in future.

All high refractive errors ≥ 5D were successfully screened in this study. Moderate refractive errors between 3D and 5D were responsible for all the false negatives. Low refractive errors and anisometropia were excluded due to near normal appearing Bruckner reflex, and these have lesser amblyogenic potential. This may, however, be considered a study limitation.

Apart from refractive errors, the photographs had 100% sensitivity for all other conditions. Clinical photographs in past have been found useful in detecting ocular conditions like retinoblastoma.[11] In this study too, the only case of retinoblastoma was successfully screened by both the ophthalmologists. Due to rarity of such occurrences and limited sample size, we cannot highlight the sensitivity and specificity of our test for specific ocular morbidities.

The next step would be to validate this test in community, in younger children, and for specific ocular morbidities. Using appropriate statistical variables for community-based screening considering confidence level of 99% (z = 2.58, P = 0.05, and d = 0.0125), a sample size of about 2500 would be required. With encouraging results of this study, we are already working on this larger study.

Using a relatively in-expensive modality like smartphone, the screening method becomes vastly economical. Compared to the photoscreeners that cost $600 in addition to significant

Figure 1: Photographs in different conditions (top to bottom) 1. Normal 2. Left esotropia 3. Hypermetropia (+4.0D) both eyes 4. Anisometropia (RE emmetropia, LE +3.0D) 5. Myopia (-6.0D) both eyes 6. Normal 7. Retinoblastoma RE 8. Anisometropia (RE emmetropia, LE +6.5D) 9. Left esotropia 10. Myopia (-4.5D) both eyes

recurring expenses, smartphones are available for $100 only.[12] This makes it an ideal screener for developing countries. As most of the analyses are based on objectifying various characteristics of Bruckner's reflex (color, size, shape, and symmetry), software can be developed for quick and accurate analyses. An artificial intelligence based system can lessen the burden of screening from limited trained human resources in developing countries, which can further economize the screening process. However, it should be understood that tests based on Bruckner reflex require a minimum standard of photograph and would require a basic training of the photographer. Also, conditions not affecting the media clarity like diseases of the optic nerve and retina are likely to be missed by this screening modality.

Conclusion

Smartphone photography is a reliable tool for detection of amblyogenic conditions in children.

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Conflicts of interest

There are no conflicts of interest.

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