Purpose: New objective photoscreeners are emerging with encouraging national guidelines and pediatric providers can be reimbursed for photoscreening.

Methods: Nine objective screeners were applied to two emmetropic subjects with or without known power contact lenses to induce spherical and cylindrical anisometropia close to American Association for Pediatric Ophthalmology and Strabismus (AAPOS) thresholds.

Results: The screeners produced near linear pupil crescents and estimated refractions for induced anisometropia. Most performed well with AAPOS 2003 validation; however, the iPhone (Apple, Cupertino, CA) was too sensitive, whereas the remote autorefractors using Vision in Preschoolers Study criteria were less sensitive.

Conclusions: The new, interpreted objective screeners appear valid for detection of anisometropia.

and duration of time. We have offered a quick and convenient method for calibration of objective photoscreeners with contact lens-induced spherical and astigmatic anisometropia.

With the introduction of three new photoscreeners, we employed our contact lens anisometropia technique compared to existing technology.

PATIENTS AND METHODS

The primary purpose of this study was to calibrate the various pediatric photoscreeners over a range of contact lens-induced hyperopic and astigmatic anisometropia near the AAPOS criteria for anisometropia (1.50 D) or axial astigmatism (>1.50 D). We also applied the AAPOS validation guidelines as if these two individuals represented different screened patients.

This study was part of the Alaska Blind Child Discovery, which has institutional review board approval from Providence Hospital, Anchorage, Alaska. The subjects were minors and consent was obtained from their parents.

Each subject underwent a comprehensive eye examination including monocular visual acuity, retinoscopy, refraction, cover testing, and stereoacuity. Two subjects (15- and 18-year-old girls) had essentially plano sphere refractions, orthophoria, and visual acuity better than 20/20 in each eye. Therefore, anisometropia in the nondominant eye was induced with placement of a known power, myopic soft contact lens. A manifest refraction was performed at least 3 minutes after insertion of each contact lens.

The following objective photoscreeners were applied to both subjects in reduced illumination rooms, for their symmetric plano sphere status, and with four different levels of anisometropia near the AAPOS anisometropia threshold of 1.50 diopters (D). Figure 1 shows the subjects holding the nine objective photoscreeners.

Nikon Retinomax

The Nikon Retinomax hand-held autorefractor (Nikon, Melville, NY) was brought into close proximity of the right and left eyes, focused through the viewing lens to generate multiple refractive estimates from which the device computed an average. Referential criteria for Retinomax and Welch Allyn Suresight were taken from the Vision in Preschoolers Study (VIPS) (Table 1).

Suresight

The Suresight hand-held, remote autorefractor (Welch Allyn, Skaneateles Falls, NY) can be set to adult refraction or child screening. The device was brought to within approximately 50 cm of the right and left eyes, an audible tone was indicated the focal...
distance, and the device was aimed with the view finder. Multiple refractive readings were generated and an average for each eye with inter-eye difference spherical equivalent was printed.

**MTI**

A retrofit MTI photoscreener (MTI, Lancaster, PA) using Fuji FP-3000B film was aimed using the triangulation white-arrow aiming beams on the forehead from approximately 1 meter. Fixation was fostered with blinking LEDs. The shutter release was pressed for a horizontal flash, 90° rotation, and the vertical flash exposed. The film was then withdrawn from the camera, allowed to develop, and the backing peeled for viewing.

**Gateway DV-S20**

The Gateway DV-S20 (Gateway, Irvine, CA) is a palm-sized, 2 megapixel, nonzoom, nonfocus digital camera with near-coaxial flash. It was aimed from 1.7 meters and two flash images were exposed (horizontal and vertical). Flash-to-lens distance was 18 mm.

**Canon TX1**

The Canon TX1 (Canon, Lake Success, NY) is a palm-sized, 7 megapixel, 10× zoom, autofocus, red-reflex reduction, override digital camera that was aimed from 2 meters with the room lights sufficiently turned up to allow autofocus with approximately 7× zoom. The patient fixated on the camera while a horizontal and vertical image was exposed. Flash-to-lens distance was 19 mm.

The Gateway DV-S20 and the Canon TX-1 are no longer commercially available; however, they may still be obtained through online purchasing.

**iPhone 4S**

The iPhone 4S (Apple, Cupertino, CA) has a near-coaxial flash and lens, but has mandatory red-reflex reduction pref lash. Flash-to-lens distance was only 5.5 mm. The flash can be set to “auto” or “full-on.” A horizontal and a vertical image were taken. The ideal distance is approximately .3 meters, but this can result in tiny pupils. We set a distance of 1.2 meters. At onset of red-eye reduction, a clear Bruckner image appears (as if instant flash), but the actual image with partial miosis was less obvious. We are not aware of an iPhone app that overrides red-eye reduction; this desirable feature is being pursued by iCheckHC (http://icheckhc.com).

**PlusoptiX S09**

The PlusoptiX S09 (PlusoptiX, Nuremburg, Germany) is an extensively validated, multi-radial, infrared, Linux-based computer-interpreted photoscreener that has evolved from the Photorefractor II and the Windows/Firewire based PlusoptiX S04 and S08. This hand-held camera connects by cable to an A/C powered small computer and a monitor. Alignment and focal distance were guided by a video image on the monitor. The subject fixated on LEDs in the camera. The age-based criteria by which the Plusoptix software refers a patient relative to refractive error, ocular alignment, and pupil size is manufacturer supplied but can also be user defined to modify for desired specificity and sensitivity. We employed the current Alaska Blind Child Discovery age-based referral criteria (Table 1).

**SPOT**

Released in late 2011, the SPOT software version 1.0.3 (PediaVision, Lake Mary, FL) is a self-contained, hand-held, battery-powered unit that has a pressure-sensitive screen for data entry and monitoring of alignment and proper focus distance. The SPOT does an estimation of pupil size, interpupillary distance, ocular alignment, and refractive error. From these, an age-based decision “pass” or “refer” is shown on the screen and incorporated in a printable report if a local printer is available by WiFi transfer. It is also possible to export a database of screening variables for each patient on input user-defined referral criteria by USB flash drive.

**iScreen 3000**

The iScreen 3000 (iScreen, Memphis, TN) was released in late 2011 as a battery-operated, hand-held version of the original desktop iScreen. The iScreen 3000 has a keyboard for data entry, a monitor, and an ethernet port for data export and import. Focus and alignment are similar to the MTI with triangulated red laser beams aimed between the eyebrows. The iScreen has a single shutter button that exposes rapid (0.1 second) sequential horizontal and vertical flash images. Once a satisfactory image is determined from the view on the monitor, the image is saved. Images can be sent via ethernet to a central iScreen interpretation center immediately or after a period of screening without turning the unit off or running out of battery.

One previous device (EyeDx; San Diego, CA) and two current devices (Visiscreen; Vision Re-
For each photoscreener that produced flash images of both pupils (all but Suresight, Retinomax, PlusoptiX, and SPOT), we used the Delta Center Crescent (DCC) method of photoscreen interpretation. The DCC method uses the central Hirschberg image rather than the border of the pupil for reference. It is therefore less dependent on measurement of pupil size. If the light crescent in the red pupil advanced to within 1 mm of the center, to the center, or past the center, these were considered “refer” even for a pupil size of 3 to 4 mm.

**RESULTS**

Validation statistics for the nine objective screeners as if there were ten separate subjects (two subjects with five refractive conditions each) through contact lens-induced anisometropia in two emmetropic subjects. Top set of statistics regards 1.50 D induced anisometropia as less than a true American Association for Pediatric Ophthalmology and Strabismus (AAPOS) amblyopia risk factor, whereas the bottom set regards 1.50 D induced anisometropia as a true AAPOS risk factor (the 2003 AAPOS guidelines define true anisometropia as > 1.50 D). PPV is positive predictive value, the percent of referred patients with true disease. Sensitivity is the percent of true disease referred by screening, whereas the specificity is the percent of passed patients who did not have disease.

Retinomax (Nikon, Melville, NY), Gateway DV-S20 (Gateway, Irvine, CA), iPhone 4s (Apple, Cupertino, CA), Canon TX-1 (Canon, Lake Success, NY), MTI MTI, (Lancaster, PA), iScreen 3000 (iScreen, Memphis, TN), Welch Allyn Suresight (Welch Allyn, Skaneateles Falls, NY), PediaVision SPOT (PediaVision, Lake Mary, FL), PlusoptiX 509 (PlusoptiX, Nuremberg, Germany).
all objective screeners on both emmetropic subjects. Manifest refractions shortly after insertion of each contact lens in the nondominant eye of each subject were consistent in the dominant eye with no contact lens and as expected over the various known power contact lenses inserted in the nondominant eye. Pupil size varied from 5 to 7.5 mm.

Photoscreen pupil crescent was measured for each digital flash image and from the iScreen output and compared using the DCC method (Figure 2).

The degree of spherical anisometropia induced by the unilateral contact lens is shown in Figure 3. A vector graphic representation of the anisometropic cylinder induced by the unilateral toric contact lens is shown in Figure 4.

**DISCUSSION**

All seven photoscreeners gave passing, normal results for emmetropia, but referred both cases with contact lens-induced anisometropic hyperopia of 2 D and 1.75 D induced axial astigmatism. There was a near linear relationship between induced refractive error and DCC in the photoscreen images and also for the reported refractive error interpreted by the remote autorefractors and the computer-interpreted photoscreeners.

Contact lens-induced 1.00 D spherical anisometropia was over-referred by iPhone, SPOT, and iScreen for one subject with more dilated pupils. Induced anisometropia at the AAPOS 2003 limit of 1.50 D was referred by Pedavision SPOT referral criteria and for the iPhone for both subjects, with mixed referral between subjects for MTI, Gateway DV-S20, Canon TX1, iScreen (± DCC interpret), and Plusoptix S09.

Using VIPS 94% specificity criteria, the SureSight and the Retinomax only referred one spherical anisometropia of 2 D, and only one of the two induced axial anisometropic astigmatism examples.

A DCC of 1 mm worked well from most photoscreeners and the iScreen; however, a DCC of 2 mm...
was better for Gateway with these subjects imaged from 2 meters and a DCC of zero was better for the iPhone imaged from 1.3 meters.

The contact lens-induced refractive error may be better for calibration than for validation. We had only two subjects and, despite wearing four different contact lenses each, this does not actually represent ten different subjects for validation. In addition, our teenager subjects with contact lens-induced anisometropia may not exactly resemble patients kindergarten age and younger for whom photoscreening is intended. Pupil size in this study was influenced by a dim room simulating the screening environment. We did not have rheostat or other control on pupil size and larger pupils tended to over-refer, whereas drowsy miotic pupils under-referred. We did not control accommodation with cycloplegia similar to real screening conditions but unlike the refractive state desired during confirmatory examination by AAPOS 2003 guidelines. The degree of accommodation at time of screening, influenced by alertness and the fixation target and screening distance varies, as seen in the origins of the induced astigmatism vectors in Figure 3.

There is good evidence that, for children capable of performing an acuity screening, earlier referral yields better acuities than school-aged referral. The assumption that even earlier referral could yield even better acuity has merit; indeed, amblyopia risk factors detected by photoscreening in toddlers can respond to amblyopia therapy better than those of their preschool counterparts.

Many advances in technology and validation have accompanied objective pediatric vision screening since the previously published guidelines. Since 2002, a procedure code has evolved from “investigational” (0065’T) to conventional (99174) with relative value units of 0.69. The pediatric primary care provider is encouraged by validation, guidelines, and insurance reimbursement to offer early objective vision screening to patients during child visits, and as a part of evaluating visual concerns in younger patients and children with developmental delays. The Alaska Blind Child Discovery recommends that valid objective screening be offered as a part of AAPOS guideline vision screening during the following age ranges: 12 to 24 months, 36 to 59 months, and at kindergarten entry; photoscreening can outperform patched acuity screening by school nurses in kindergarten and pre-kindergarten students.

This current study suggests that all nine objective screeners were capable of sorting cases with refractive error in normal range from those with amblyopiogenic, induced hyperopic anisometropia. An experienced central reading center is recommended for interpretation of photo screen images. The iPhone with preflass when exposed from a distance of greater than 1 meter was too sensitive; a modification in the iPhone’s mandatory, red-eye reduction preflass would be beneficial were it to become a clinical photoscreener exposed less than 1 meter from the patient. Pediatricians should be aware that parents will likely find leukocoria with iPhoto flash images of their children; these are unlikely to imply retinoblastoma, but consistent and asymmetric red reflex images warrant further attention, including Enhanced Bruckner Test, office photoscreening, and/or pediatric ophthalmology referral. High specificity and positive predictive value are encouraging to parents, pediatricians, payors, and pediatric ophthalmologists. Using VIPS 94% specificity cut-offs, the Suresight and the Retinomax had low sensitivity. The current immediate, or prompt, interpreted photoscreeners (PlusoptiX S09, iScreen 3000, and SPOT) all performed well and would be beneficial in efforts by pediatric care providers to detect amblyopia early enough for therapy to be efficacious.

REFERENCES