de WIT: The Evaluation of Two New Computer-Based Tests for Measurement of Aniseikonia: Discussion

- ORIGINAL SCIENTIFIC ARTICLES -

ARNOLD RW, STARK, LEMAN, ARNOLD KK, and ARMITAGE: Tent Photoscreening and Patched HOTV Visual Acuity by School Nurses: Validation of the ASD-ABCD Protocol

LAM, CHENG, KIRSCHEN and LABY: Effects of Head Tilt on Stereopsis

- MEETING REPORT -


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Tent Photoscreening and Patched HOTV Visual Acuity by School Nurses: Validation of the ASD-ABCD Protocol
(Anchorage School District - Alaska Blind Child Discovery program)

Robert W. Arnold, M.D1, Lee Stark, RN2, Rachel Leman3,4, Koni K. Arnold, RN, MHA3, and M. Diane Armitage, CO1

from (1) Ophthalmic Associates, (2) Anchorage School District, (3) Grace Christian School, and (4) University of Alaska, School of Nursing, Anchorage, Alaska

ABSTRACT: Background: Novel objective tests of risk factors for amblyopia offer an alternative for preschool vision screening. We compared the merits of photoscreening versus portable patched acuity testing in elementary schools. Photoscreening may outperform routine acuity testing in pediatric offices; however, both have fairly good validity when performed by specialists in preschool vision screening.

Methods: School nurses performed patched HOTV surround acuity testing and two types of photoscreening (MTI and Gateway DV-S20) in a portable tent near each classroom.

Results: 1700 children (696 1st grade, 710 Kindergarteners, and 271 special-needs pre-Kindergarten). 14% had comprehensive exams and another 65% had normal photoscreens combined with patched acuities of 20/20 or better OU. We estimate the overall sensitivity/specificity using AAPOS guidelines for the modalities to be 39%:99% for patched HOTV acuity, 77%:99% for MTI photoscreening, and 85%:98% for Gateway photoscreening. The specificity of acuity testing was particularly low in pre-K due to 33% unable to complete the test, but about 80% of initial acuity failures were able to pass with pinhole.

Conclusion: Tent photoscreening in younger elementary school children was more sensitive and faster than patched acuity particularly in developmentally delayed preschoolers.

Received for consideration November 2, 2007; accepted for publication January 18, 2008.

Financial Disclosure: None of the authors receive any direct compensation from the included vision screen marketers or their competitors. Dr. Arnold coordinates the Alaska Blind Child Discovery program that has received discount vision screening technology from MTI, EyeDx, iScreen, JVC, Gateway, Welch Allyn, the Amblyopia Foundation of America and Eye Care and Cure. Dr. Arnold is an investigator and protocol developer for the Pediatric Eye Disease Investigator Group.

Correspondence/reprint requests to: Dr. Arnold, Pediatric Ophthalmology and Strabismus, Ophthalmic Associates, 542 West Second Avenue, Anchorage, Alaska 99501-2242. Fax: 907-278-1705.

Email: eyedoc@alaska.net
INTRODUCTION

Preschool vision screening now has favor of evidence-based medicine.

Vision screening, seeking to detect treatable amblyopia, satisfies most of the World Health Organization criteria for screening particularly when applied to preschoolers in developed countries with strong amblyopia treatment emphasis. The Vision In Preschoolers (VIP) Studies recently demonstrated different sensitivities for a predefined 90% specificity for various objective and subjective screening tests in neurologically normal preschoolers. The Amblyopia Treatment Studies by the Pediatric Eye Disease Investigator Group (PEDIG) has consistently used threshold surround HOTV logMAR optotypes and adherent patching of the non-tested eye; this precludes subject “peeking” even when tested by experienced pediatric eye doctors or orthoptists. Objective photoscreening outperforms conventional visual acuity testing in preschool vision testing by pediatric nurses. It is difficult to obtain a high community penetration with a large-scale school vision screening program. We obtained a high specificity using the MTI photoscreener and experienced photographers and then adapted inexpensive digital flash cameras for photoscreening.

In recent local studies with photoscreening school-aged children, large numbers of occult amblyopes were detected. We therefore trained school nurses to perform vision screening in school according to the ASD-ABCD protocol. In this study the results are compared against two standards, which we term “gold” and “silver” standards, to determine the validity of the screening protocol.

METHODS

The vision screening protocol of the Alaska Blind Child Discovery program had initial institutional review 1996 by Providence Hospital. It was adapted for public school use and received approval from the Institution Review authorities for the Anchorage School District.

A screening protocol was devised and thoroughly reviewed with interested administrators and elementary school nurses representing the 62 public elementary schools in Anchorage and the Grace Christian School.

Visual acuity was tested using a slightly modified surround logMAR HOTV 10-foot flip-card book designed by Wendy Marsh-Tootle (Cat # 2021; Precision Vision, LaSalle, Ill). Students were seated next to the tent described below, and held the HOTV matching card separated by a ten-foot nylon cord from the HOTV flip book held by the nurse. To enhance acceptance by young children, we pre-printed child-friendly occlusion patches. Preschoolers had to achieve at least 20/40 acuity and an inter-eye difference of two or less lines. Kindergarten and first graders had to achieve 20/32 and an inter-eye difference of two or less lines. If children were unable to pass, they were offered the option to view the chart through an array of pinholes on their matching card, or to try to read a custom near-card of surround HOTV letters scaled to ten inches (Figure 1, right, next page). We categorized these as “fail acuity” but “pinhole or near pass.” Visual acuity testing preceded photoscreening and was performed just outside the tent.

One of the greatest challenges to achieving low false positives from photoscreening is to have pupils dilated and the child fixing directly on the camera without the distraction of looking at classmates or the face of the nurse. Therefore, photoscreening was done with two different cameras in a specially designed, portable tent erected a short distance from the classroom being tested. The tents were of opaque, heavy cotton cloth covering PVC pipe frames with dimensions 183 cm long, by 76 cm wide by 130 cm high. (Figure 2, right, next page).

The first photoscreen was taken with a previously calibrated, miniature digital flash video/still camera called the Gateway DV-S20 (Gateway computer company). Students were
Figure 1 (Arnold et al): Modified Surround (four bars) HOTV near visual acuity card (Cat # 2021; Precision Vision, LaSalle, Ill.): “V” when folded down; with Matching card spectacles with multiple pinholes. HOTV near card scaled to ten inches.

Figure 2 (Arnold et al): Special screening tent made of opaque cloth over a PVC pipe frame (6 ft L x 2.5 ft W x 4.5 ft H) for photoscreening in school. Patched student holds HOTV matching card separated from the surround HOTV flip cards with a ten-foot nylon cord. MTI photoscreener rests on traveling case.
 uniqueness identified with a large adhesive patch on their upper torso to be included in the photoscreen images. This camera had a fixed flash intensity and “focus” and was taken from a distance 1.6 m from the students face. At least one image was taken with the camera oriented vertically and then the camera was rotated LCD screen down, for a subsequent image similar to the automated sequential orthogonal images of MTI intended to detect astigmatism. Then a retrofit MTI camera was used to take one or more sequential, orthogonal flash photoscreen images. The intensity of the MTI camera flash exceeded that of the Gateway DV-S20. The luminance of the tent was controlled with the back flap to allow minimum localization of the student. Both the Gateway and MTI cameras operate on batteries, however an A/C adapter was used to decrease flash cycle time. Two centralized 2 hour teaching sessions trained the nurses in advance of screening their schools, and two mentor nurses (KKA and LS) traveled to each school to apprentice and assist in the screening process.

Parents or guardians consented to this additional screening effort. On each ABCD consent form, additional information was gleaned including whether previous eye exam had been done and by whom,\(^1\). The questionnaire health data was not included in determining “pass” or “refer,” however notes were included if a parent noted a warning sign (i.e misalignment or white pupil) or other symptom of serious eye disease.

The digital and Polaroid photoscreen images were physician-interpreted at the ABCD Coordinating Center with results conveyed to the school nurses and mailed directly to parents. Referral was identified for photoscreens whose light crescent was within 1 mm of the center of the pupil (“Delta-center crescent;” a simplified interpretation criteria that resembles the pupil-size protocol at Vanderbilt University\(^1\)) or students with photographic evidence of manifest strabismus, blepharoptosis or anisocoria.

For those students’ consent/data forms with written evidence of prior eye exam or spectacle use, school nurses contacted eye doctors for information on comprehensive (with or without cycloplegia) eye examinations for pass or refer interpretations. ABCD differentiates between “comprehensive” and “confirmatory” exams; both include assessment of monocular visual acuity, binocular alignment, media clarity, cycloplegic refractive error and retina. However the “confirmatory exam” indication was a high risk sign or symptom referral and the doctor allocates more time and effort. Students for whom either the patched acuity, or the Gateway photoscreen, or the MTI photoscreen were interpreted as “not normal” were urged to have a confirmatory eye examination with cycloplegic refraction from their nearest convenient eye doctor and to send results from that examination back to the ABCD coordinating center, or to the school nurse.

For validation, two different outcome standards were utilized since this screening did not require all non-refer students to also obtain a confirmatory exam. Our “gold standard” exam positive and negative was for those children who had confirmatory exams. We devised a second standard (“silver standard”) by adding all those children with patched acuities of 20/25 or better in each eye and normal photoscreens, both cameras, added to the negative confirmatory exam column. We also evaluated those children treated with spectacles who, presumably as a result of their treatment, were able to pass the acuity testing, but demonstrated referral red-reflex images without their spectacles during photoscreening. The gold-standard exam criteria for positive or negative were determined from the published recommendations of the AAPOS Vision Screening Committee\(^1\). An additional validation criteria, the ABCD statistic (i.e. ABCD specificity) includes un-screenable, or un-interpretable screenings in the denominator\(^1\).

**RESULTS**

During 4 months of the spring semester of 2004, 1700 Anchorage elementary school children from 20 schools were vision screened by
TABLE I: RESULTS: Tent Photoscreening & HOTV VA by ASD-ABCD protocol, of 696 Children, Raw Data

<table>
<thead>
<tr>
<th>Acuity</th>
<th>Incomplete</th>
<th>Positive</th>
<th>Normal</th>
<th>Total</th>
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</thead>
<tbody>
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<td>pre-K HOTV</td>
<td>18</td>
<td>31</td>
<td>149</td>
<td>270</td>
</tr>
<tr>
<td>K HOTV</td>
<td>117</td>
<td>139</td>
<td>1444</td>
<td>1700</td>
</tr>
<tr>
<td>F HOTV</td>
<td>8</td>
<td>45</td>
<td>643</td>
<td>710</td>
</tr>
<tr>
<td>Gateway</td>
<td>20</td>
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<td>preK Gateway</td>
<td>6</td>
<td>57</td>
<td>207</td>
<td>270</td>
</tr>
<tr>
<td>K Gateway</td>
<td>10</td>
<td>101</td>
<td>618</td>
<td>729</td>
</tr>
<tr>
<td>F Gateway</td>
<td>4</td>
<td>76</td>
<td>616</td>
<td>696</td>
</tr>
<tr>
<td>MTI</td>
<td>39</td>
<td>185</td>
<td>1476</td>
<td>1700</td>
</tr>
<tr>
<td>preK MTI</td>
<td>11</td>
<td>44</td>
<td>216</td>
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<tr>
<td>K MTI</td>
<td>11</td>
<td>73</td>
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<td>729</td>
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<tr>
<td>F MTI</td>
<td>16</td>
<td>66</td>
<td>614</td>
<td>696</td>
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</table>

Raw data breakdown by class (F = first grade, K = Kindergarten and pre-K = preschool) and referral classification Anchorage School children screened with 10-foot, patched surround HOTV acuity card (HOTV), Gateway DV-S20 digital flash camera and MTI photoscreener. Almost all of the “incomplete” are due to untestable acuities, while ~30% of incomplete photoscreens were not testable and the remainder “inconclusive” due to small pupils or film problems.

TABLE II: RESULTS: GOLD STANDARD: Tent Photoscreening & HOTV VA by ASD-ABCD protocol, of 234 Children, validated by Gold exam

<table>
<thead>
<tr>
<th>HOTV</th>
<th>sensitivity</th>
<th>specificity</th>
<th>ABCD sens</th>
<th>ABCD spec</th>
<th>PPV</th>
<th>NPV</th>
<th>prescreen Prob</th>
<th>ABCD prescreen</th>
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</thead>
<tbody>
<tr>
<td>P</td>
<td>59%</td>
<td>78%</td>
<td>23%</td>
<td>31%</td>
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<td>49%</td>
<td>56%</td>
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<tr>
<td>K</td>
<td>41%</td>
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<td>84%</td>
<td>80%</td>
<td>71%</td>
<td>39%</td>
<td>42%</td>
</tr>
<tr>
<td>F</td>
<td>36%</td>
<td>96%</td>
<td>32%</td>
<td>92%</td>
<td>73%</td>
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<tr>
<td>total</td>
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<td>76%</td>
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<th>specificity</th>
<th>ABCD sens</th>
<th>ABCD spec</th>
<th>PPV</th>
<th>NPV</th>
<th>prescreen Prob</th>
<th>ABCD prescreen</th>
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<td>89%</td>
<td>84%</td>
<td>42%</td>
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<tr>
<td>F</td>
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<td>94%</td>
<td>84%</td>
<td>91%</td>
<td>84%</td>
<td>97%</td>
<td>25%</td>
<td>26%</td>
</tr>
<tr>
<td>total</td>
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<td>95%</td>
<td>75%</td>
<td>92%</td>
<td>91%</td>
<td>88%</td>
<td>38%</td>
<td>39%</td>
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<table>
<thead>
<tr>
<th>Gateway</th>
<th>sensitivity</th>
<th>specificity</th>
<th>ABCD sens</th>
<th>ABCD spec</th>
<th>PPV</th>
<th>NPV</th>
<th>prescreen Prob</th>
<th>ABCD prescreen</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>69%</td>
<td>96%</td>
<td>69%</td>
<td>96%</td>
<td>96%</td>
<td>70%</td>
<td>56%</td>
<td>56%</td>
</tr>
<tr>
<td>K</td>
<td>81%</td>
<td>80%</td>
<td>79%</td>
<td>79%</td>
<td>74%</td>
<td>86%</td>
<td>41%</td>
<td>42%</td>
</tr>
<tr>
<td>F</td>
<td>96%</td>
<td>96%</td>
<td>92%</td>
<td>94%</td>
<td>88%</td>
<td>98%</td>
<td>26%</td>
<td>26%</td>
</tr>
<tr>
<td>total</td>
<td>80%</td>
<td>91%</td>
<td>78%</td>
<td>90%</td>
<td>85%</td>
<td>88%</td>
<td>39%</td>
<td>39%</td>
</tr>
</tbody>
</table>
Figure 3: ABOVE (Arnold et al) Validation (TEST SENSITIVITY VS SPECIFICITY) separated by grade level for surround HOTV visual acuity testing, MTI and Gateway DV-S20 photoscreening. GOLD STANDARD EXAMS, n=234. See also bold text next page ->

Figure 4: BELOW (Arnold et al) IDEM Figure 3 above, MODIFIED to favor tests with low rates of “incomplete” or “inconclusive” results. See also emboldened text NEXT page.
Using this portion all the children screened, the ABCD prescreen probability of eye disease was 39% (56% of pre-K). The positive predictive value was 79% for patched HOTV, 83% for Gateway and 91% for MTI photoscreening. The overall sensitivity and specificity were 44% and 92% for patched HOTV acuity, 80% and 95% for MTI photoscreening, and 80% and 91% for Gateway photoscreening (see Figure 3 on prior facing page). Figure 4, bottom of prior facing page is the same as Figure 3 however the ABCD sensitivity and specificity are plotted giving advantage to any screening test with a low “incomplete” or “inconclusive” interpretation rate.

We then combined the 234 known comprehensive exams with all children capable of resolving 10-foot, patched surround HOTV acuity 20/25 or better with normal Gateway and MTI photoscreens to arrive at a “silver standard” exam total of 1340 students (79%), see Table 3, below. Using this enhanced portion of all the children screened, the ABCD prescreen probability of eye disease was reduced to 9% (30% of pre-K). The overall sensitivity and specificity were 39% and 99% for patched HOTV acuity, 77% and 99% for MTI photoscreening, and 85% and 98% for Gateway photoscreening without and with the ABCD statistics (see Figure 5 and 6, next two pages).
The average time to test with HOTV was 143±58 sec (SD), the time to test with MTI was 82±27 seconds while the time to test with Gateway DV-S20 was 41±10 seconds. The estimated direct cost to screen with patched HOTV was 12 cents (includes patch), for MTI was $3.75 and for Gateway was 11 cents. We did not account for personnel time, additional time moving to and from the classroom (though the tent was much closer than the nurses office), nor

Figure 5: (Arnold et al.) Silver Standard Validation of 1340 of the 1700 students by adding to the 234 Gold standard confirmatory exams all those students who had 20/25 patched acuity or better in each eye plus both photoscreening tests also normal.
did we account for record keeping and parental notification time because these remain a part of prior conventional screening and the ASD-ABCD protocol.

The breakdown of refer photoscreen impressions was 29% hyperopia, 28% astigmatism, 16% myopia, 15% anisometropia, 4% strabismus and the remaining 8% blepharoptosis, cataract and “Brückner” anomaly. Ten developmentally delayed pre-K students were untestable and objected to the patch. The pinhole modification of the HOTV matching card was not universally employed by nurses for acuity refers, however 41 passed with pinhole (GSE 5

**Figure 6: (Arnold et al) Silver Standard Validation using modified ABCD criteria favoring screening modalities with low rates of inconclusive interpretations. N=1340.**
true threshold astigmatism and 3 false) and 10 did not improve with pinhole (GSE true); this improved positive predictive value 6%. In no case did near acuity add to pinhole interpretation.

CONCLUSION

One clear advantage of school screening is the chance to increase community penetrance of screening during the amblyopia-sensitive period, potentially with a legal mandate. Despite published guidelines that all children receive the AAP serial battery of objective and eventually subjective screening during pediatric exams or the American Optometric Association recommended battery of 5 comprehensive eye exams, many American children are not thus screened. Even statewide charitable preschool efforts fail to achieve levels of community penetrance. In addition, the pediatric nurse routine 4-year-old visual acuity testing without occlusion of the non-tested eye may miss some cases of treatable eye disease. Compared to other lay persons, school nurses are specifically trained to screen children. About 5% of school nurses time is devoted to health screening.

The ideal validation test of a screening test for a relatively uncommon disease like amblyopia is very time and labor intensive and costly because it required confirmatory exams of a large number of screened individuals from a non-disease-enhanced cohort. A less complete validation for actual community screening can report positive predictive value (PPV) which is the portion of referred individuals who meet the pre-defined confirmatory exam criteria. Photoscreening with centralized interpretation has higher positive predictive value (PPV) than pediatrician-office acuity testing and has somewhat better PPV than the manufacturer’s referral criteria on the Welch-Allyn SureSight. Compared to the first phase of VIPS, with a disease-augmented cohort of 2588 preschool children “screened” by licensed eye professionals (experienced pediatric optometrists), our school-aged study may demonstrates better validation of photoscreening but fairly similar validation on the acuity testing. Our self-funded effort lacked the NIH-funded universal comprehensive exam criteria of VIPS. Unfortunately the criteria by which VIPS identified “true” positives differs from the previously published AAPOS standards making direct comparisons between our conclusions less reliable. There are certain ocular conditions that qualify as “True” by AAPOS standards that would be easily missed by an acuity test, or a photoscreen such as a compensated intermittent exotropia or a high hyperopia with sufficient accommodation. On the other hand, young patients with insufficient accommodation and moderate hyperopia may yield photoscreens with interpretation of “refer”. We were impressed with the VIPS reported performance of the remote autorefractor Welch-Allyn SureSight and will continue to compare it with simple photoscreeners. The ability to interpret onsite of the Suresight (with VIPS retrospectively altered referral criteria) and acuity testing offer school nursing advantages over methods of photoscreening that require centralized interpretation.

We had limited number of children with comprehensive exams prior to the school screening, and these overemphasized children with otherwise recognizable pathology (overt strabismus) or who had been detected by prior screening efforts. Some of the children who had received normal exams during a routine trip to the family eye doctor. Of the children detected by our screening effort, some had occult refractive amblyopia, entered the Amblyopia Treatment Study, and have already been effectively treated. In addition to the gold standard confirmatory exams, we analyzed validation with our “silver standard” exam that also included all those children whose school acuity was 20/25 or better, and for whom both photoscreens were interpreted as normal. We are confident our “silver standard” did not include patients with significant amblyopia, but this group could have included students with above AAPOS threshold levels of hyperopia, astigmatism and/or intermittent strabismus.
Again, this study was limited since it lacked confirmatory exam on all screened children, the “silver standard” only approximates true complete validation, and only one physician performed the photoscreen interpretations not completely blinded to other history information about the student. However, we feel that acuity testing with AAP referrals levels with Surround HOTV flip cards appears moderately valid for testing children Kindergarten level and older, but may be supplanted by an objective test like photoscreening particularly in younger children in a school environment. The addition of pinhole retesting for those children who failed the patched HOTV acuity reduced false positives and would have only missed some cases of myopia and astigmatism. We are in accord with AAP guidelines to assure monocular testing, the adhesive patches were well tolerated by almost all of the students. Fixation and pupil dilation with the photoscreeners was probably enhanced by the tent.

REFERENCES:


