

Implementation of Instrument-Based Vision Screening for Preschool-Age Children in Primary Care

Jonathan R. Modest, MBA, MPH,^a Katherine M. Majzoub, RN, MBA,^b Bruce Moore, OD,^c Vijeta Bhambhani, MS, MPH,^d Sarah R. McLaughlin, MPH,^a Louis Vernacchio, MD, MSc^{a,e,f}

BACKGROUND: Vision screening is an essential element of well-child care for young children. Recently, several professional groups have recommended the use of instrument-based screening; however, studies demonstrating the effectiveness of this technique in pediatric primary care settings are lacking.

METHODS: We designed a cluster randomized quality improvement project to test the implementation of instrument-based vision screening for 3- to 5-year-old children within a pediatric primary care network. The program consisted of 12 pediatric practices randomized into phase 1 and phase 2 groups. We evaluated the effect of the intervention on completed vision screening at well-child visits, family satisfaction, and referrals to eye care specialists.

RESULTS: Instrument-based vision screening increased completed screening among 3- to 5-year-old children from 54% to 89% in the phase 1 group and from 65% to 92% in the phase 2 group. Improvement was most marked among 3-year-old children, with completed screening increasing from 39% with chart-based screening to 87% with instrument screening. Family satisfaction was higher with instrument screening. In addition, instrument screening was associated with a 15% reduction in referrals to eye care specialists.

CONCLUSIONS: Instrument-based vision screening for preschool-aged children can be effectively implemented into primary care practice, results in substantially improved rates of completed vision screening at well-child visits, and may result in a reduction in unnecessary referrals to eye care specialists. Additional research is needed regarding how best to overcome barriers to the widespread use of this technology in pediatric primary care settings, as well as its longer-term effect on referrals and the prevalence of amblyopia.

Pediatric vision screening is an essential element of well-child care for young children given the importance of adequate vision to overall cognitive and social development. Appropriate vision screening in young children can detect amblyopia or amblyogenic risk factors at a time when treatment

is effective, ideally before age 5 years, as well as serious but rare eye diseases, such as cataracts and neuroblastoma.¹⁻⁴ Therefore, the major professional organizations concerned with children's vision, including the American Academy of Pediatrics, the American Academy

abstract

^aPediatric Physicians' Organization at Children's, Brookline, Massachusetts; ^bPrevent Blindness, Boston, Massachusetts; ^cNew England College of Optometry, Boston, Massachusetts; ^dChildren's Hospital Integrated Care Organization, Boston, Massachusetts; ^eDivision of General Pediatrics, Boston Children's Hospital, Boston, Massachusetts; and ^fDepartment of Pediatrics, Harvard Medical School, Boston, Massachusetts

Mr Modest designed the project and the analysis and interpreted the findings, and drafted the manuscript; Mrs Majzoub and Dr Moore designed the project and the analysis and interpreted the findings; Ms Bhambhani and Ms McLaughlin performed the analysis and interpreted the findings; Dr Vernacchio designed the project and the analysis, performed the analysis, interpreted the findings, and drafted the manuscript; and all authors revised and approved the manuscript.

Ms Bhambhani's current affiliation is Division of Cardiology, Massachusetts General Hospital, Boston, MA.

DOI: <https://doi.org/10.1542/peds.2016-3745>

Accepted for publication Mar 9, 2017

Address correspondence to Louis Vernacchio, MD, MSc, Pediatric Physicians' Organization at Children's, Children's Hospital Boston, 77 Pond Ave, Suite 205c, Brookline, MA 02445. E-mail: louis.vernacchio@childrens.harvard.edu

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

Copyright © 2017 by the American Academy of Pediatrics

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

To cite: Modest JR, Majzoub KM, Moore B, et al. Implementation of Instrument-Based Vision Screening for Preschool-Age Children in Primary Care. *Pediatrics*. 2017;140(1):e20163745

of Ophthalmology, the American Association for Pediatrics Ophthalmology and Strabismus, and the American Association of Certified Orthoptists, have recommended vision screening beginning in early childhood for all children.^{5,6} To date, the standard of care has relied heavily on optotype-based screening techniques, such as picture tests (eg, Lea Symbols) and letter charts (eg, HOTV or Snellen) for distance visual acuity and the Random Dot E test or similar for stereovision (hereafter, referred to as chart-based vision screening), but research has shown that such testing is limited in real-world primary care settings by a number of factors, including patient cooperation and the relatively high level of staff training and expertise needed to perform testing appropriately.^{7–11} Our previous work found that even an extensive training program for primary care practices led to only small increases in successful screening rates among 4- and 5-year-old children and no improvement among 3-year-old children.¹² With the current status quo, the rate of amblyopia in the United States has been stable at 2% to 3%, well above what it could be if efficient and effective primary care-based screening and referral techniques were in place.¹³

Given the limitations of chart-based vision screening, several professional groups have recently recommended replacing its use in young children with instrument-based screening using portable photoscreeners or autorefractors.^{14,15} The current generation of these devices demonstrates high sensitivity/specificity relative to a gold standard comprehensive eye exam.^{16,17} Furthermore, in field testing, instrument screeners show high rates of testability when performed in settings such as Head Start by using trained testers.¹⁸ To date, however, no studies have demonstrated how effectively these

	Run-in Phase	Early Phase	Late Phase	
Week	0	7	15	25
Phase 1 practices	Behavioral screening	Instrument-based screening	Instrument-based screening	
Phase 2 practices	Behavioral screening	Behavioral screening	Instrument-based screening	

FIGURE 1
Project timeline.

instruments can be implemented in busy primary care settings, which will be necessary for widespread vision screening among young children to be accomplished. Thus, we designed a quality improvement (QI) project to determine how effective the implementation of instrument-based vision screening for preschool-aged children would be in the primary care setting and what effect it would have on referrals to eye care specialists. Our principal aim was to increase successfully completed vision screening of 3- to 5-year-old children at well visits within a group of pilot practices from a baseline of ~60% using chart-based screening to at least 85% using instrument screening.

METHODS

QI Intervention

The Pediatric Physicians' Organization at Children's (PPOC) is an independent practice association of >80 privately-owned pediatric practices affiliated with Boston Children's Hospital that provides primary care to an estimated 400 000 children throughout eastern Massachusetts. We invited applications from all 56 practices that had participated in our previous QI project to optimize chart-based vision screening¹² to apply to participate in the project. We received applications from 22 eligible practices and randomly selected 12 practices to participate by using random number generation. Practices were stratified by size (≤ 4 vs ≥ 5

physicians) and then randomized into phase 1 or phase 2 arms by using random number generation.

The project consisted of 3 phases: a 7-week run-in phase (November 17, 2014 to January 5, 2015), during which all 12 practices used chart-based vision screening processes consisting of visual acuity testing using Lea symbol charts and stereovision testing using Random Dot E testing; an 8-week early phase (January 6 to March 2, 2015), during which phase 1 practices began instrument-based screening while phase 2 practices continued using chart-based vision screening; and a 10-week late phase (March 3 to May 8, 2015), during which phase 1 practices continued to use instrument-based screening and phase 2 practices began using instrument screening (Fig 1).

The device we chose for instrument-based screening was the SPOT Vision Screener (Welch-Allyn, Skaneateles Falls, NY), a binocular vision screener with acceptable sensitivity and specificity versus the gold standard vision exam.^{19–23} Participating practices received "out-of-the-box" training, as would be provided to any new purchaser of the device, consisting of a 30-minute review by a company sales professional. We built structured text fields into each participating practice's electronic health record, with the goal of capturing standardized results for both chart-based and instrument-based screening throughout the project.

Throughout the course of the project, we asked practices to offer parents/guardians a brief survey to capture the patient/family experience associated with the screening type used during their visit. This survey consisted of 2 questions: (1) “On a scale of 0 to 10 (0 = not confident at all; 10 = extremely confident), how confident are you that today’s vision screening correctly captured your child’s ability to see?”; and (2) “On a scale of 0 to 10 (0 = not satisfied at all; 10 = extremely satisfied), how satisfied overall are you with the vision screening your child received today?”

Electronic Health Record Analysis

All routine check-up visits for 3- to 5-year-old children seen during the study period in each of the participating practices were identified through our network’s central electronic health record database. Patients for whom it was documented that they were under the care of an eye care specialist were excluded from additional analysis. For each visit, evidence of vision screening was searched for in the structured data fields built for the study and also in any other part of the record where vision screening results may have been captured. For chart-based screening, we deemed vision screening to have been fully completed if results for visual acuity testing in each eye and stereovision were documented. For instrument screening, we deemed vision screening to be complete if a result (“Pass” or “Complete Eye Exam Recommended”) was documented.

Referral Analysis

To quantify the effect of the implementation of instrument-based screening on referrals to eye care specialists, we used administrative claims data from 2 major commercial insurance companies that share such data with PPOC. For this analysis, we compared the rate of initial visits

(*Current Procedural Terminology* codes 99201-5, 99241-5, 92002, and 92004) to ophthalmologists and optometrists for children 3 to 5 years of age at the time of the visit from 2 years before implementation through 1 year after implementation for practices participating in the instrument-based screening project to those for control PPOC practices who were not part of the project and employed chart-based screening throughout the time period analyzed. To determine if the difference in visit trends was significant, we modeled the difference in visit rates (rate for project practices minus rate for control practices) using linear regression accounting for autocorrelation over time.²⁴

Statistical process control analyses were performed with QI MacroS (KnowWare International, Denver, CO). All other analyses were performed with SAS version 9.4 (SAS Institute, Inc, Cary, NC). This project was reviewed by the Boston Children’s Hospital Committee on Clinical Investigation and deemed to meet our institution’s definition of QI and was therefore exempt from the requirement for individual informed consent.

RESULTS

The 6 practices randomized to phase 1 had a median of 7 medical providers (range: 3–13) and a median patient panel size of 4771 (range: 2215–8280). The corresponding numbers for the 6 phase 2 practices were 4.5 (range: 2–15) and 3651 (range: 1957–9676). A total of 18% of patients of phase 1 practices were publicly insured (range for individual practices: 7%–52%) compared with 15% of phase 2 practices (range for individual practices: 2%–37%).

Figure 2 demonstrates the project’s principal finding, screening results by study phase. During the run-in phase, with both groups employing

chart-based screening, 172 of 316 patients (54.4%) adequately completed screening in the phase 1 group, and 231 of 354 patients (65.3%) completed screening in the phase 2 group. In the early study phase, the phase 1 group switched to instrument screening with 342 of 380 children (90.0%) adequately completing screening, whereas the phase 2 group continued to use chart-based screening with 338 of 508 children (66.5%) completing screening. In the late period, with both groups using instrument screening, the phase 1 group adequately screened 484 of 545 children (88.8%), whereas the phase 2 group adequately screened 571 of 621 children (91.9%).

Statistical process control charts demonstrate that a special-cause increase in the proportion of adequately screened children occurred immediately coincident with the introduction of instrument screening in both the phase 1 and phase 2 group, and performance was maintained consistently thereafter in both groups (Fig 3). Eleven out of the 12 practices in the project experienced a statistically significant improvement in completed vision screening with instrument screening compared with chart-based screening (Table 1).

As shown in Fig 4, the switch to instrument screening had the largest effect on the screening of 3-year-old children, with an increase in adequately completed screening from 156 of 404 children (38.6%) using chart-based screening to 479 of 505 children (87.1%) using instrument screening ($P < .0001$). Statistically significant improvements were also seen for 4-year-old children (279 of 405 children [68.9%] using chart-based screening to 455 of 493 children [92.3%] using instrument screening; $P < .0001$) and 5-year-old children (306 of 369 children [82.9%] using chart-based screening

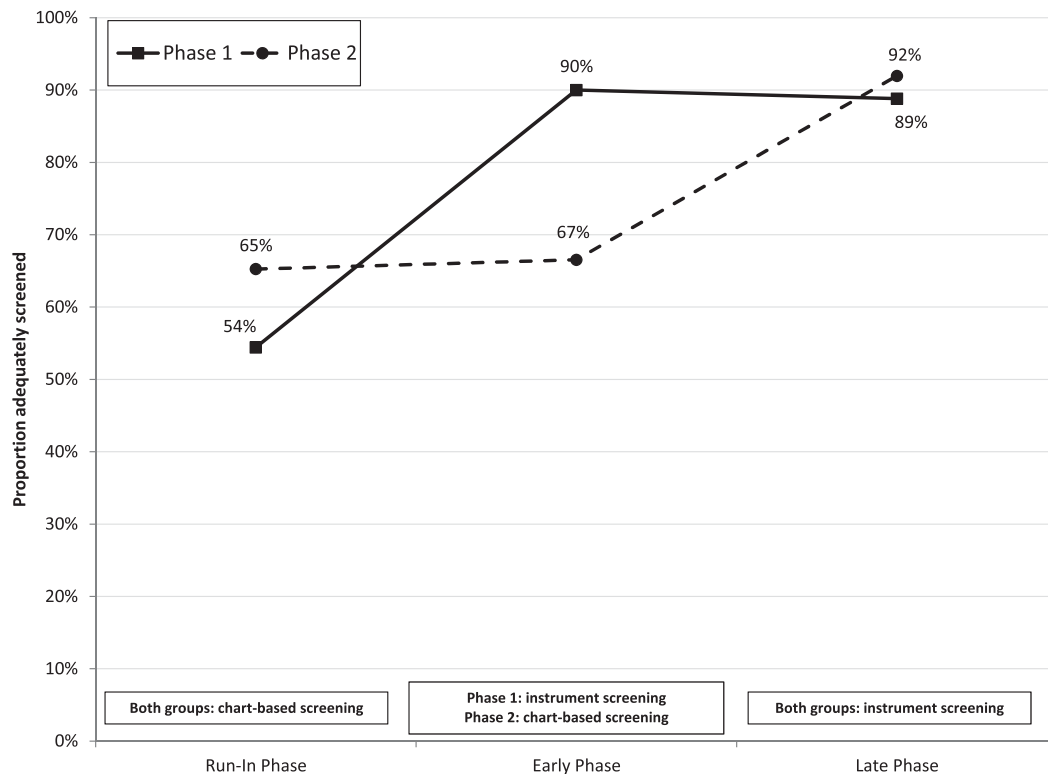


FIGURE 2 Proportion of 3-, 4-, and 5-year-old children adequately completing vision screening by study phase.

to 463 of 503 children [92.0%] using instrument screening; $P < .0001$).

To additionally understand the reasons for the failure of patients to be screened in the instrument screening cohorts, we analyzed the documentation for such patients. Of the 1546 total patients eligible for instrument screening, 149 (9.6%) were not adequately screened. Of the 149 patients not adequately screened, there was no documentation of an attempt among 137 (8.9% of the total), and there was documentation of an unsuccessful attempt among 12 (0.8% of the total).

A brief family experience survey was fielded in a convenience sample of project participants. Families of 137 of 1178 patients (11.7%) undergoing chart-based screening completed the survey as did families of 631 of 1546 (40.8%) patients undergoing instrument screening. In response to the question “On a scale of 0 to 10 (0 = not confident at all; 10 =

extremely confident), how confident are you that today’s vision screening correctly captured your child’s ability to see,” the mean among those undergoing chart-based screening was 8.2 (SD: 2.3) vs 8.6 (SD: 1.8) for those undergoing instrument screening ($P = .04$). In response to the question “On a scale of 0 to 10 (0 = not satisfied at all; 10 = extremely satisfied), how satisfied overall are you with the vision screening your child received today,” the mean among those undergoing chart-based screening was 8.4 (SD: 2.1) vs 8.9 (SD: 1.6) for those undergoing instrument screening ($P = .02$).

The impact of instrument screening on initial visits to eye care specialists is shown in Fig 5. During the preimplementation period, there was no discernible difference in the quarterly rate between project participants (82.6 visits per 1000 patient-years) and controls (81.8 visits per 1000 patient-years). In the postimplementation period, after

both phase 1 and phase 2 practices instituted instrument screening plus 1 quarter of additional lag time for referrals to eye care specialists to occur, the rate of initial visits to ophthalmologists and optometrists among participants (62.1 visits per 1000 patient-years) was 15.1% lower than that of controls (73.2 visits per 1000 patient-years; $P = .04$ for the difference in rates over time).

DISCUSSION

This QI project, consisting of a cluster randomized implementation of instrument-based vision screening in primary care pediatric practices, demonstrated clear superiority of instrument screening over chart-based screening in terms of testability for preschool-aged children. Our principal aim of increasing the proportion of 3- to 5-year-old children successfully screened at well visits to at least 85% was achieved. Notably,

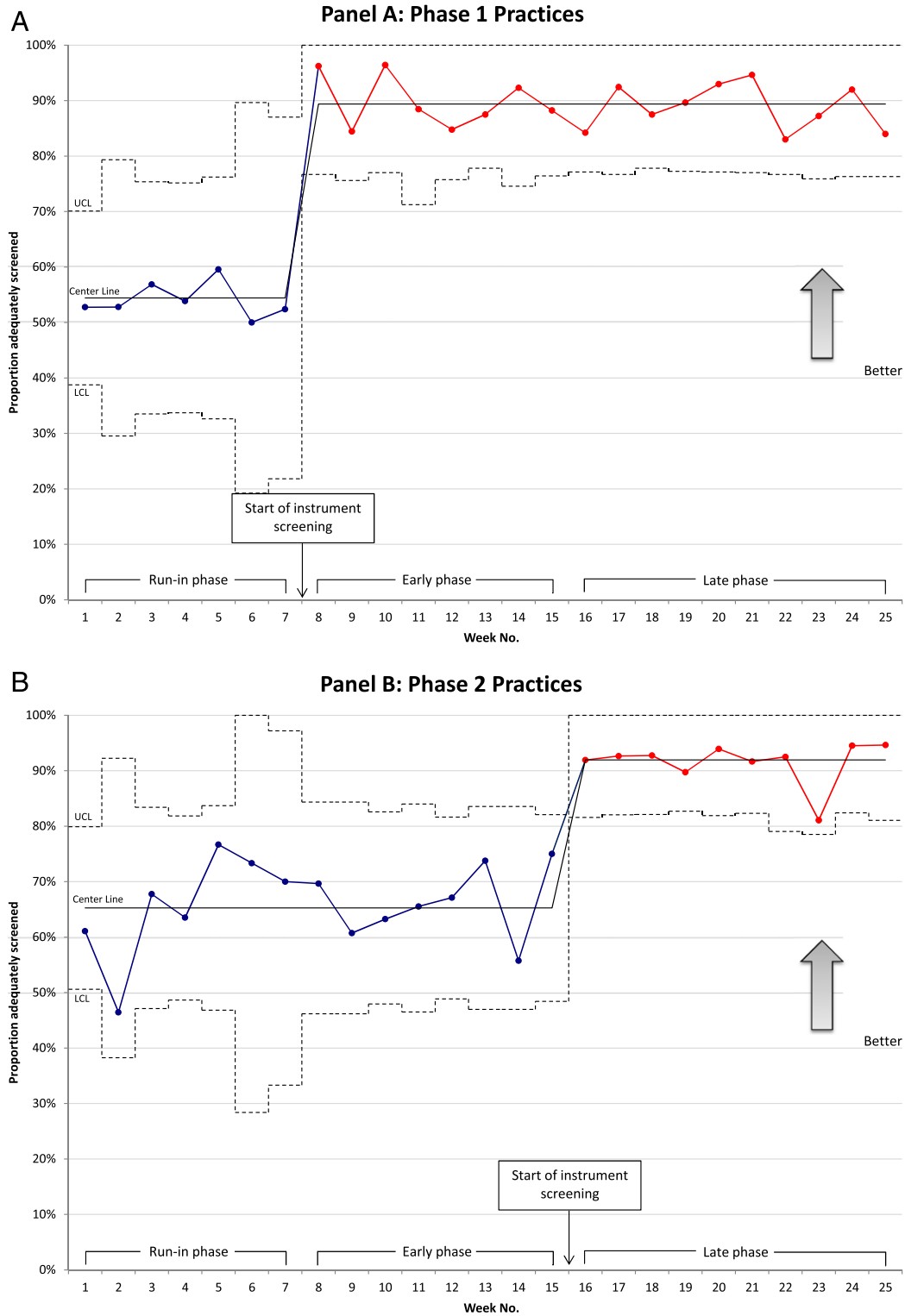


FIGURE 3 Statistical process control charts of proportion of 3-, 4-, and 5-year-old children completing vision screening by week. A, Phase 1 practices; B, phase 2 practices. Points in red indicate special cause variation relative to the baseline period. LCL, lower control limit; UCL, upper control limit.

improvement was achieved in 11 out of 12 participating practices with instrument screening; the 1

practice that did not experience a statistically meaningful improvement started with a relatively high level of

success using chart-based screening. The fact that the improvement was nearly immediate on implementing

instrument screening, was relatively uniform across practices, and was achieved with minimal training suggests that similar improvement should be achievable by other practices instituting this technology.

Improvement was observed for each age evaluated (children at 3, 4, and 5 years of age), but was most impressive among 3-year-old children. Indeed, instrument screening nearly entirely closed the testability gap between 3-year-old and 4- to 5-year-old children seen with chart-based screening.^{7,10,25,26}

Reducing the age of successful routine screening holds the promise of detecting amblyopia or amblyogenic risk factors at earlier ages when treatment is most effective.¹⁻⁴ Based on our experience with this project, the improvement seen with instrument screening relates to the success of this technique in addressing the major barriers to chart-based vision

TABLE 1 Successfully Completed Vision Screening by Individual Practice

	Chart-Based Screening	Instrument Screening	P
	Numerator/Denominator (%)	Numerator/Denominator (%)	
Phase 1 practices			
1	52/88 (59.1)	229/263 (87.1)	<.001
2	41/82 (50.0)	232/242 (95.9)	<.001
3	28/51 (54.9)	145/154 (94.2)	<.001
4	32/52 (61.5)	106/123 (86.2)	<.001
5	16/21 (76.2)	70/87 (80.5)	.66
6	3/22 (13.6)	44/56 (78.6)	<.001
Phase 2 practices			
7	237/279 (84.9)	204/212 (96.2)	<.001
8	103/148 (69.6)	91/109 (83.5)	.011
9	118/158 (74.7)	84/87 (96.6)	<.001
10	41/140 (29.3)	94/99 (94.9)	<.001
11	44/82 (53.7)	58/74 (78.4)	.001
12	26/55 (47.3)	40/40 (100.0)	<.001

screening, primarily: limitations of preschool-aged children’s ability to focus and complete the testing; limitations of adequate distraction-free space to complete chart-based screening; and the need for staff training and expertise with chart-based screening techniques.¹² Additionally, staff reported that the time to complete instrument-based screening in young children

(typically <1 minute) was substantially shorter than that for chart-based screening (typically several minutes), an important consideration for busy primary care practices.

Although our project achieved an ~90% successful screening rate with instrument screening, it is important to note that there was documentation

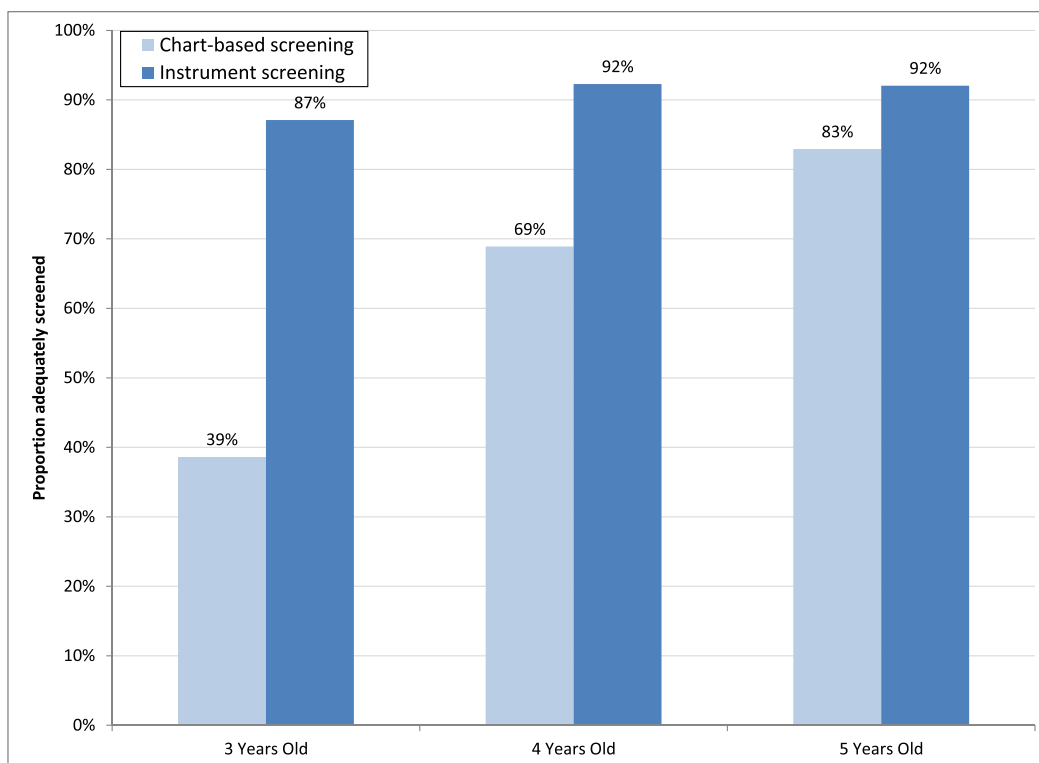


FIGURE 4 Proportion of children adequately completing vision screening by age and method.

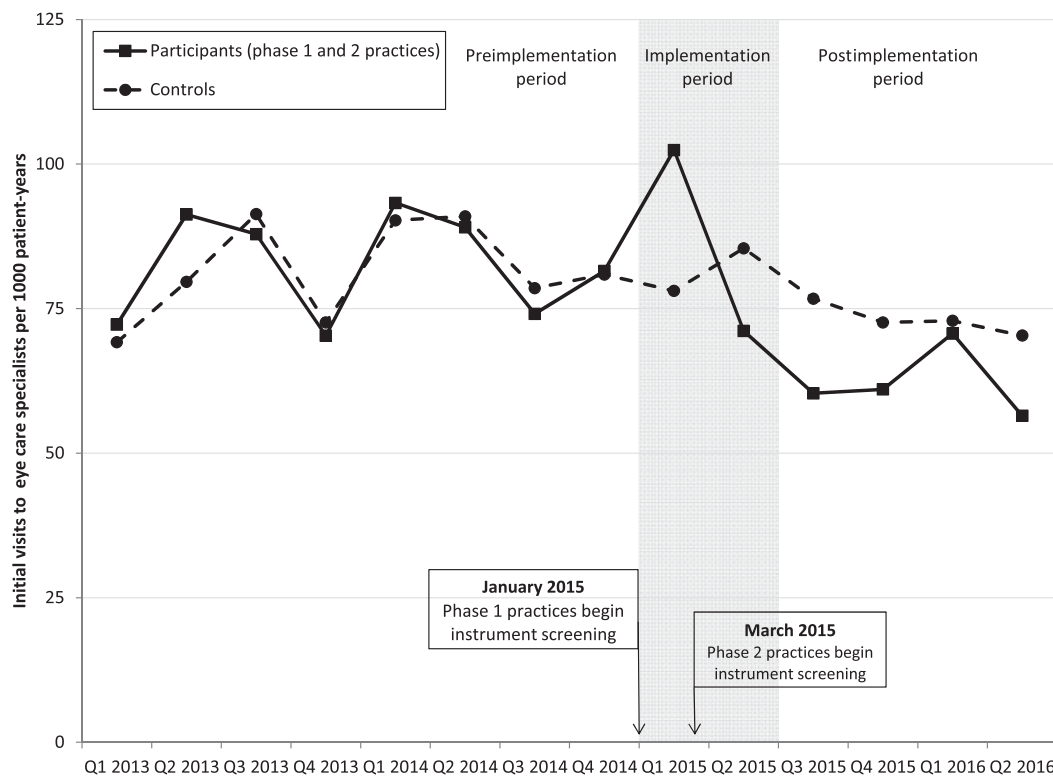


FIGURE 5

Initial visits to ophthalmology and optometry for children 3 to 5 years of age among participants and controls.

that instrument screening was attempted but unsuccessful in only 1% of cases. In the other ~9% of unscreened children, no attempt was documented, and we were unable to ascertain from our data whether these represented failed attempts at instrument screening or instances where no screening was attempted. Other published reports of testability in young children by using automated devices suggest that the untestable proportion is closer to 1% than 10%,^{16,17,20,27,28} but these studies were not from primary care settings and additional study to define the untestable proportion in clinical primary care settings would be useful. This analysis also points out that the availability of effective technology does not guarantee that a preventive care service, such as vision screening, will be reliably delivered at busy primary care visits. As we know from data on other recommended services that are not reliably performed, the

human element of QI is still critical to achieve high levels of performance.²⁹

In addition to an improvement in detecting potentially treatable vision conditions in young children, we hypothesized that instrument screening may also reduce unnecessary referrals to eye care specialists. We based this hypothesis on previously published data from our network indicating that ~40% of children referred to eye specialists were found to have no diagnosed vision condition³⁰; such patients were presumably referred because of an inability to cooperate with chart-based screening and/or false-positive results. Indeed, in the current project, participating practices saw a reduction in new referrals to ophthalmologists and optometrists among 3- to 5-year-old children of ~15% after the implementation of instrument screening compared with control practices using chart-based screening. It is not clear whether the reduction in referrals we experienced

would occur in other networks; such depends on their preexisting vision screening practices and referral patterns. However, if our experience with referral rates is sustained over time and replicated by others, it would suggest that instrument screening will be cost-effective for the health care system in the long run, because even a small reduction in the rate of unnecessary referrals to specialists would over time compensate for the cost of the equipment. It could also potentially lead to improved access to specialty services for children with vision conditions, especially in places underserved by pediatric eye care specialists.

The major strength of this work lies in its direct applicability to the pediatric primary care setting. The practices involved received no training on instrument screening other than the standard out-of-the-box training provided by the manufacturer's sales representative and yet found immediate success

screening young children. Thus, we believe other practices who implement instrument screening with the same or similar devices should be able to replicate our results. In our view, the principal challenges to widespread adoption of this new technology lie in the several thousand dollar start-up cost, which may be prohibitive, especially for small practices, and a lack of reimbursement for this service from many insurance companies.³¹ Indeed, although such instruments have been available for several years now, their use in pediatric primary care settings appears to be limited thus

far.⁸ In addition, technical questions remain with the use of instrument-based screening that need resolution, including the risk of missing significant hyperopia that may be clinically significant.^{32,33} The ultimate question that remains to be answered is whether instrument-based screening among young children in the primary care setting will reduce long-term rates of amblyopia.

among 3-, 4-, and 5-year-old children with instrument-based screening compared with chart-based vision screening. Additional study is needed into methods of overcoming barriers to widespread use of this new technology, its effect on rates of referral to eye care specialists, and, ultimately, its long-term effect on the prevalence of amblyopia in the population.

CONCLUSIONS

This QI program demonstrated significant improvement in completed vision screening at well-child visits

ABBREVIATIONS

PPOC: Pediatric Physicians' Organization at Children's
 QI: quality improvement

FUNDING: Funded by internal funds of the Pediatric Physicians' Organization at Children's.

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

REFERENCES

- Eibschitz-Tsimhoni M, Friedman T, Naor J, Eibschitz N, Friedman Z. Early screening for amblyogenic risk factors lowers the prevalence and severity of amblyopia. *J AAPOS*. 2000;4(4):194–199
- Williams C, Northstone K, Harrad RA, Sparrow JM, Harvey I; ALSPAC Study Team. Amblyopia treatment outcomes after screening before or at age 3 years: follow up from randomised trial. *BMJ*. 2002;324(7353):1549
- de Koning HJ, Groenewoud JH, Lantau VK, et al. Effectiveness of screening for amblyopia and other eye disorders in a prospective birth cohort study. *J Med Screen*. 2013;20(2):66–72
- Solebo AL, Cumberland PM, Rahi JS. Whole-population vision screening in children aged 4-5 years to detect amblyopia. *Lancet*. 2015;385(9984):2308–2319
- Village EG; Committee on Practice and Ambulatory Medicine, Section on Ophthalmology. American Association of Certified Orthoptists; American Association for Pediatric Ophthalmology and Strabismus; American Academy of Ophthalmology. Eye examination in infants, children, and young adults by pediatricians. *Pediatrics*. 2003;111(4 pt 1):902–907
- Cotter SA, Cyert LA, Miller JM, Quinn GE; National Expert Panel to the National Center for Children's Vision and Eye Health. Vision screening for children 36 to <72 months: recommended practices. *Optom Vis Sci*. 2015;92(1):6–16
- Kemper AR, Wallace DK, Patel N, Crews JE. Preschool vision testing by health providers in the United States: findings from the 2006-2007 Medical Expenditure Panel Survey. *J AAPOS*. 2011;15(5):480–483
- Kemper AR, Clark SJ. Preschool vision screening in pediatric practices. *Clin Pediatr (Phila)*. 2006;45(3):263–266
- Ciner EB, Schmidt PP, Orel-Bixler D, et al. Vision screening of preschool children: evaluating the past, looking toward the future. *Optom Vis Sci*. 1998;75(8):571–584
- Wasserman RC, Croft CA, Brotherton SE; American Academy of Pediatrics. Preschool vision screening in pediatric practice: a study from the Pediatric Research in Office Settings (PROS) Network. *Pediatrics*. 1992;89(5 pt 1):834–838
- Wall TC, Marsh-Tootle W, Evans HH, Fargason CA, Ashworth CS, Hardin JM. Compliance with vision-screening guidelines among a national sample of pediatricians. *Ambul Pediatr*. 2002;2(6):449–455
- Modest JR, Johnston SC, Majzoub KM, et al. Results of a primary care-based quality improvement project to optimize chart-based vision screening for preschool age children. *J AAPOS*. 2016;20(4):305–309
- Powell C, Hatt SR. Vision screening for amblyopia in childhood. *Cochrane Database Syst Rev*. 2009;(3):CD005020
- Miller JM, Lessin HR; American Academy of Pediatrics Section on Ophthalmology; Committee on Practice and Ambulatory Medicine; American Academy of Ophthalmology; American Association for Pediatric Ophthalmology and Strabismus; American Association of Certified Orthoptists. Instrument-based pediatric vision screening policy statement. *Pediatrics*. 2012;130(5):983–986
- US Preventive Services Task Force. Vision screening for children 1 to 5 years of age: US Preventive Services Task Force Recommendation statement. *Pediatrics*. 2011;127(2):340–346

16. Schmidt P, Maguire M, Dobson V, et al; Vision in Preschoolers Study Group. Comparison of preschool vision screening tests as administered by licensed eye care professionals in the Vision In Preschoolers Study. *Ophthalmology*. 2004;111(4):637–650
17. Kulp MT; Vision in Preschoolers Study Group. Findings from the Vision in Preschoolers (VIP) Study [published correction appears in *Optom Vis Sci*. 2009;86(8):1026]. *Optom Vis Sci*. 2009;86(6):619–623
18. Vision in Preschoolers Study Group. Preschool vision screening tests administered by nurse screeners compared with lay screeners in the vision in preschoolers study. *Invest Ophthalmol Vis Sci*. 2005;46(8):2639–2648
19. Silbert DI, Matta NS. Performance of the Spot vision screener for the detection of amblyopia risk factors in children. *J AAPOS*. 2014;18(2):169–172
20. Garry GA, Donahue SP. Validation of Spot screening device for amblyopia risk factors. *J AAPOS*. 2014;18(5):476–480
21. Peterseim MM, Papa CE, Wilson ME, et al. The effectiveness of the Spot Vision Screener in detecting amblyopia risk factors. *J AAPOS*. 2014;18(6):539–542
22. Arana Mendez M, Arguello L, Martinez J, et al. Evaluation of the Spot Vision Screener in young children in Costa Rica. *J AAPOS*. 2015;19(5):441–444
23. Peterseim MMW, Davidson JD, Trivedi R, Wilson ME, Papa CE, Cheeseman EW. Detection of strabismus by the Spot Vision Screener. *J AAPOS*. 2015;19(6):512–514
24. Penfold RB, Zhang F. Use of interrupted time series analysis in evaluating health care quality improvements. *Acad Pediatr*. 2013;13(suppl 6):S38–S44
25. Kvarnström G, Jakobsson P. Is vision screening in 3-year-old children feasible? Comparison between the Lea Symbol chart and the HVOT (LM) chart. *Acta Ophthalmol Scand*. 2005;83(1):76–80
26. Kemper AR, Helfrich A, Talbot J, Patel N, Crews JE. Improving the rate of preschool vision screening: an interrupted time-series analysis. *Pediatrics*. 2011;128(5). Available at: www.pediatrics.org/cgi/content/full/128/5/e1279
27. Borchert M, Wang Y, Tarczy-Hornoch K, et al. Testability of the Retinomax autorefractor and IOLMaster in preschool children: the Multi-ethnic Pediatric Eye Disease Study. *Ophthalmology*. 2008;115(8):1422–1425, 1425.e1
28. Dahlmann-Noor AH, Vrotsou K, Kostakis V, et al. Vision screening in children by Plusoptix Vision Screener compared with gold-standard orthoptic assessment. *Br J Ophthalmol*. 2009;93(3):342–345
29. Mangione-Smith R, DeCristofaro AH, Setodji CM, et al. The quality of ambulatory care delivered to children in the United States. *N Engl J Med*. 2007;357(15):1515–1523
30. Vernacchio L, Muto JM, Young G, Risko W. Ambulatory subspecialty visits in a large pediatric primary care network. *Health Serv Res*. 2012;47(4):1755–1769
31. Schwartz RH, Schuman AJ, Wei LL. Instrument-based vision screening: update and review. *Contemp Pediatr*. 2014. Available at: <http://contemporarypediatrics.modernmedicine.com/contemporary-pediatrics/content/tags/amblyopia/instrument-based-vision-screening-update-and-review>. Accessed August 24, 2015
32. Peterseim MMW, Papa CE, Wilson ME, et al. Photoscreeners in the pediatric eye office: compared testability and refractions on high-risk children. *Am J Ophthalmol*. 2014;158(5):932–938
33. Kulp MT, Ciner E, Maguire M, et al; VIP-HIP Study Group. Uncorrected hyperopia and preschool early literacy: results of the Vision in Preschoolers-Hyperopia in Preschoolers (VIP-HIP) Study. *Ophthalmology*. 2016;123(4):681–689