Learning from a Distance: Effectiveness of Online Spirometry Training in Improving Asthma Care

James W. Stout, MD, MPH; Karen Smith, MD; Chuan Zhou, PhD; Cam Solomon, PhD; Allen J. Dozor, MD; Michelle M. Garrison, PhD; Rita Mangione-Smith, MD, MPH

From the Departments of Pediatrics and Health Services (Drs Stout, Mangione-Smith, and Zhou), University of Washington, Seattle, Wash; Interactive Medical Training Resources (iMTR) (Drs Stout and Smith), Child Health Institute, University of Washington, Seattle, Wash; Center for Child Health, Behavior, and Development, Seattle Children's Hospital Research Institute (Drs Solomon, Mangione-Smith, Zhou, and Garrison), Seattle, Wash; and Department of Pediatrics, New York Medical College, Valhalla, NY (Dr Dozor)
Address correspondence to James W. Stout, MD, MPH, University of Washington, Child Health Institute, Suite 110, 6200 NE 74th Street, Seattle, WA 98115 (e-mail: jstout@uw.edu).

ABSTRACT

OBJECTIVE: We evaluated the effectiveness of a virtually delivered quality improvement (QI) program designed to improve primary care management for children with asthma.
METHODS: Thirty-six physicians, nurses, and medical assistants from 14 primary care pediatric practices (7 matched practice pairs) participated in a cluster randomized trial from October 2007 to September 2008. All practices received a spirometer and standard vendor training. A 7-month QI program delivered during the study period included: 1) Spirometry Fundamentals™ CD-ROM, a multimedia tutorial; 2) case-based, interactive webinars led by clinical experts; and 3) an internet-based spirometry quality feedback reporting system. Practice pairs were compared directly to each other, and between-group differences were analyzed with the use of mixed effects regression models. Our main outcome measures were the frequency of spirometry testing, percentage of acceptable quality spirometry tests, asthma severity documentation, and appropriate controller medication prescribing.
RESULTS: Participating practices uploaded a total of 1028 spirometry testing sessions, of which 340 (33.1%) were of acceptable quality. During the 7-month intervention period, there was no difference between intervention and control practices in the frequency of spirometry tests performed. Intervention practices were estimated to have significantly greater odds of conducting tests with acceptable quality compared with matched control practices, adjusting for quality in the baseline period (odds ratio 2.85; 95% confidence interval 1.78–4.56, $P < .001$). Intervention providers also had significantly greater odds of documenting asthma severity during the intervention period (odds ratio 2.9, 95% confidence interval 1.8–4.5; $P < .001$). Although use of controller medications among patients with persistent asthma approached 100% for both groups, the proportion of asthma patients labeled as persistent increased from 43% to 62% among intervention practices, and decreased from 57% to 50% among controls (NS).
CONCLUSIONS: A multifaceted distance QI program resulted in increased spirometry quality and improved assessment of asthma severity levels. Successful participation in QI programs can occur over distance.

KEYWORDS: cluster randomized controlled trial; pediatric asthma; primary care; quality improvement; spirometry

WHAT'S NEW

Lack of training and feedback for diagnostic spirometry are major barriers to its successful incorporation in primary care. A 7-month online training and feedback program addressed this need and enabled improvement in the quality of spirometry and asthma care in intervention practices.

UNDERESTIMATION OF THE severity of asthma occurs when determined on the basis of symptoms alone[1–3] and can lead to inadequate controller medication use[2,4] and increased morbidity,[5–7] healthcare use, and cost.[8–11] The EPR-3 asthma guidelines now recommend spirometry for diagnosis and management for all patients with asthma 5 years and older.[1] Most (65%) pediatricians report not using spirometry for routine asthma care.[12] Most spirometry

tests performed in primary care also fail to meet basic American Thoracic Society (ATS) quality criteria.[13,14]

There are valid reasons for these shortcomings in primary care. The spirometric procedure is technique-dependent, typically requiring training and feedback. Lack of time and training are cited as the most common barriers to its use in primary care, and most providers desire such training.[12] Staff turnover can further complicate these barriers.

Quality improvement (QI) efforts have demonstrated improvement in asthma care. One report of a hospital-based teaching clinic demonstrated increased use of asthma action plans, recorded asthma severity level, and controller medication use 3 years after the intervention.[15] Another program linked pay-for-performance incentives with training and demonstrated increased use of controller medications, asthma action plans, and flu vaccine.[16] Both interventions were delivered in person, and neither focused

on spirometry. Although not focused on asthma, an internet- and phone-based program targeting access to primary care services also reported significant and sustained improvements.[17]

Building on this evidence, we aimed to develop, deliver, and evaluate a spirometry training and feedback program delivered entirely by distance. The virtual training reported here combined interactive QI strategies delivered by internet and telephone that incorporated both self-paced and simultaneous distance learning and feedback regarding spirometry testing quality. The program aimed to improve the management of asthma in pediatric practices by increasing both the frequency of spirometry testing and the quality of those tests. We hypothesized the following causal pathway: Increased frequency and quality of spirometry testing would increase the documentation of asthma severity, thereby increasing the rate of appropriate controller medication use. Please see a related video at http://www.academicpedsjnl.net/content/acap-videos.

METHODS

Collaborators at the New York Department of Health identified 28 potentially eligible pediatric practices from their asthma QI consortium in September/October 2007. Eight of these practices did not adequately match other eligible practices. Sixteen of the remaining 20 practices were enrolled (eligible response rate = 80%; Fig. 1). Thus, 8 practice pairs were matched on the following criteria: number of pediatric providers (±1); urban versus suburban/rural location; percent of Medicaid-eligible patients (±15%); and type of practice (private practice, hospital-based clinic, school-based clinic, public clinic). Internet access was also required.

Representatives from all 16 practices attended an in-person introductory meeting in New York led by investigators (R.M.-S. and J.W.S.), and each practice in a matched pair was randomly assigned to the intervention or control group. The University of Washington's Institutional Review Board approved the research protocol and documents.

THE INTERVENTION

The distance QI program was designed to increase the frequency and improve the quality of spirometry testing, thereby increasing complete asthma severity assessments and appropriate controller medication use. Twenty-one pediatric providers (17 physicians and 4 nurse practitioners) and their support staffs (18 medical assistants or nurses) participated in the intervention, which spanned 7 months and included 3 components:

1. Spirometry Fundamentals™ multimedia CD-ROM, is a 70-minute, 10-module interactive tutorial developed at University of Washington for training healthcare providers in spirometry performance and interpretation.[18]
2. WebEx is a computer-based virtual meeting software enabling clinical experts to lead interactive case-based sessions with participant response and question-and-answer opportunities.[19] Five hour-long webinars developed by our authors (K.S., A.J.D., J.W.S.) were delivered over 7 months to a combination of providers and support staff. These webinars focused on the proper administration and interpretation of spirometry, incorporating these results into asthma severity classification, and then accurately choosing therapy. The curriculum also included other asthma care elements, such as the use of written action plans, structured encounter forms, planned asthma visits, and patient registries, which were made available through the internet. Current versions of these sessions are available at www.spirometrytraining.org [20]
3. All participating practices used an internet-based spirometry reporting software developed by BioMedical
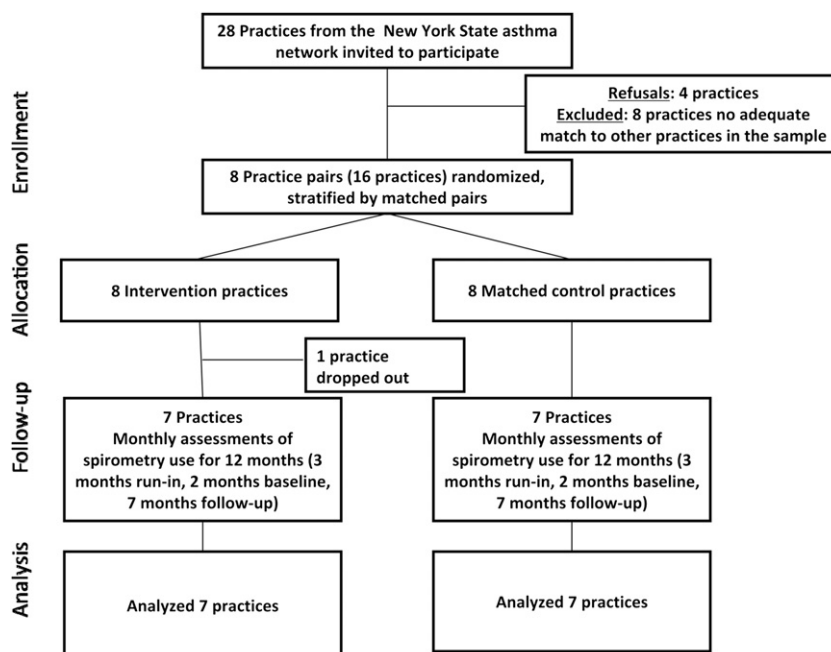

Figure 1. *Flow chart.*

Systems that interfaced with the ndd EasyOne Diagnostic spirometer. All spirometry tests produced during the study period were stripped of all patient-specific information other than patient age and uploaded to a secure website by intervention (and control) practices. Project faculty remotely evaluated these tests using a letter grade system based on ATS quality criteria (Table 1). Six monthly feedback reports summarizing the quality of spirometry technique were distributed by e-mail to the identified lead providers at each practice for distribution to their teams 4 to 8 weeks after the tests were conducted.[14]

Control group practices received the full on-line training and 4 months of feedback reporting at the conclusion of the study period.

DATA COLLECTION

SPIROMETRY TESTING DATA

In October 2007, spirometer sales representatives delivered standard spirometer training and user support to all practices. The first 3 months after the practices received spirometers and software (10/1/07-12/31/07) were considered the "run-in" phase, when participants familiarized themselves with the equipment and uploading process and when technical problems were addressed.

Control and intervention providers (not study protocol) decided which patients needed spirometry throughout the study period and were asked to transmit their spirometry data on a weekly basis. Each time spirometry data were uploaded, all new tests since the previous upload date were automatically detected and sent by the EasyData software to the study database. Practice providers therefore had no control over which tests were transmitted for analysis. Monthly frequency and quality of spirometry testing were assessed for all practices during a 2-month baseline period (1/1/08-2/28/08) and a 7-month intervention period (3/1/08-9/12/08; Fig. 2). After the baseline period, intervention practices began the distance learning QI program.

All transmitted spirometry sessions included an ATS-based quality grade (A, B, C, D, or F) automatically calculated by the EasyOne spirometer. These grades are frequently inaccurate compared with visual inspection, so each transmitted testing session was over-read by a registered respiratory therapist blinded to study group, who also assigned a letter grade. For this analysis, only grades of "A" and "B" were equal to ATS test performance standards and considered to be of acceptable quality.[14]

Kappa statistics were calculated to examine interrater reliability of the grading system comparing grades assigned by the blinded respiratory therapist and a second unblinded grader (J.W.S.). The Kappa was 0.65 indicating moderate interrater reliability.[21]

MEDICAL RECORD ABSTRACTION

To assess whether changes occurred in the frequency of appropriately documenting asthma severity and prescribing controller medications, we abstracted 270 deidentified medical records of children with asthma from study practices during the 10 months before and 8 months after the start of the intervention. We did not use these data to assess whether spirometry had been performed. We asked all practices to identify medical records for 35 children who were 5 to 18 years as of 5/1/07, seen by participating providers, and receiving an asthma billing code at least once during the previous 20 months (5/1/07-11/30/08). Encounters within this 20-month time frame were abstracted if asthma was addressed as either the primary or secondary concern. All identifiers were stripped from the medical records by the practice sites before mailing them to the study team for abstraction. These data could not be linked to the uploaded spirometry data since both data sources were deidentified.

Documentation of asthma severity required use of the terms established in the EPR 2002 Update (our protocol pre-dated the 2007 asthma guideline): mild intermittent, or mild, moderate, or severe persistent asthma.[22] "Appropriate treatment" was defined as a controller medication prescription for a child labeled with persistent asthma.

To assess interrater reliability, 2 team members (R.M.-S. and J.W.S.) blinded to study arm assignment each reabstracted a 5% sample of the medical records. Kappa statistics for assessing whether severity was documented, level of asthma severity, and whether controllers were prescribed, were 0.81, 0.91, and 0.79, respectively, indicating good to almost perfect interrater reliability.[21]

Table 1. American Thoracic Society Spirometry Quality Grading Criteria

Grade	Criteria	Comments
A	At least 3 acceptable tests (for age ≤6 years: 2 acceptable) AND the difference between the best 2 FEV_1* and FVC values is equal to or less than 150 mL (for age ≤6 years: ≤100 mL or 10% of FVC, whichever is greater)	Meets all current ATS standards: 2005 ATS Standards for older than age 6 and 2007 Standards for ≤6 years
B	At least 3 acceptable tests AND the difference between the best 2 FEV_1 and FVC values ≤200 mL	Meets older ATS Standards, published 1995
C	At least 2 acceptable tests AND the difference between the best 2 FEV1 and FVC values ≤250 mL (or 1 acceptable test for ≤6 years of age)	Categorized as out of compliance with standards but may still be clinically useful
D	1 acceptable test or 2 acceptable tests >250 variance	Generally not recommended for use unless normal percent predicted reported
F	No acceptable efforts	Not useful

*ATS = American Thoracic Society; FEV_1 = forced expiratory volume in one second; FVC = forced vital capacity.
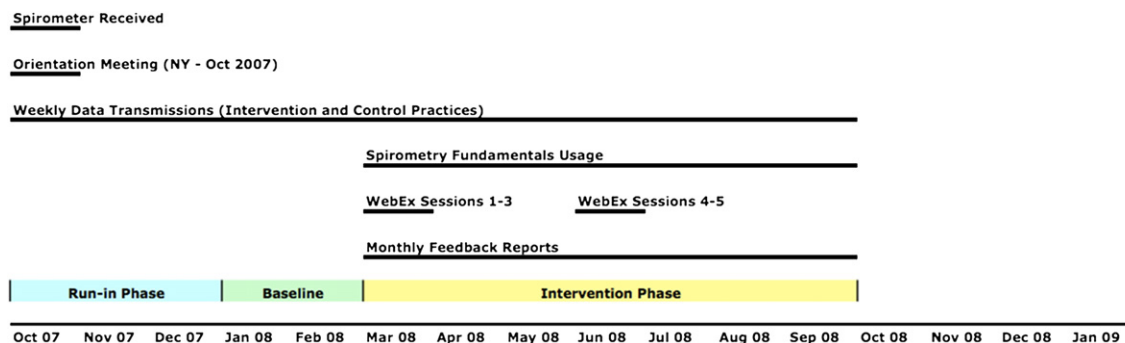
Figure 2. *Learning from a distance study timeline.*

SAMPLE SIZE CALCULATIONS

On the basis of data from a previous National Institute for Occupational Safety and Health study examining spirometry use in primary care practices (P. Enright, personal communication, February 2007), we expected all practices to perform an average of 8 (SD = 5) spirometry tests per month. We hypothesized that intervention practices would double the number of spirometry tests performed to 16 tests per month. A sample size of 8 practices per arm provided 80% power (alpha = .05) to detect an increase from 8 to 15 spirometry tests performed per month in the intervention period. A loss of 2 matched practice pairs (equating to 2 practices per study arm) would still provide 80% power to detect an increase from 8 to 16 spirometry tests per month in the intervention period, assuming full compliance with spirometry session uploading.

The 8 practice pairs were estimated to provide 84% power to detect an increase of 30% in test passing rate in the intervention arm from a control rate of 20%, assuming seven repeated assessments and an intraclass correlation 0.05.

ANALYTIC METHODS

The unit of analysis was the practice site; therefore, all analyses took this hierarchical data structure into account and adjusted for within-practice clustering of care processes. For each randomly assigned matched practice pair, we applied mixed-effects regression models[23] with random effects, to account for the correlations among observations as the result of repeated measures within practice and the paired matching.

We aggregated the number of spirometry tests performed during the intervention period to the practice level and compared the control group with intervention group using both paired *t*-tests and paired Wilcoxon tests. Both tests yielded similar results.

The 2 main outcomes (spirometry test frequency and the percentage with acceptable quality) were further compared between control and intervention groups with the use of mixed-effects regression models. Monthly data from each practice were treated as repeated measures. Linear regression was conducted on test frequency, and logistic regression was conducted on test quality. The passing percentage of spirometry tests during the baseline interval was adjusted in the test quality regression as a baseline quality measure to account for high-performing practices during the baseline period. As our primary analysis, we conducted an intention-to-treat analysis of all enrolled practices, even though one practice didn't provide any outcome data during the intervention period and 2 other practices submitted only one curve. To account for correlations caused by repeated assessments within a practice and matched pairing, a practice random effect and a pair random effect were included in the regression models. These mixed effects models were fitted using the lme4 package within R statistical software version 2.13.2.[24]

To reliably assess the percentage of acceptable quality spirometry testing sessions, we also performed a sensitivity analysis on practices with >1 test for the 7-month period under consideration. With only one submission, a practice could only have an acceptable quality estimate of 0 or 100%; either extreme could potentially bias the results.

To examine the intervention effects on documentation of asthma severity, we constructed a post-test, fixed-effects conditional logistic regression model. For appropriate use of controller medications, small numbers did not allow for multivariate analysis, so we instead compared appropriate controller medication use separately for each study period by using the Fisher exact test. Stata was used for these analyses.[25]

RESULTS

Sixteen practices (8 matched pairs) were recruited and enrolled, but one intervention practice dropped out because of competing priorities, leaving 7 matched practice pairs. Most practices (11/14) provided care primarily for Medicaid-insured populations. Most practices were urban, ranged in size from a solo practice to 10-provider practices, and represented a variety of practice types (Table 2). The number of participants in the intervention practices ranged from 1 to 6 providers. Seven of the 8 intervention practices had 1 to 3 Medical Doctors (MDs; 6 practices) or 1 Pediatric Nurse Practitioner (PNP; 1 practice) and 1-3 Medical Assistants (MAs; 7 practices) participating in the study and training program. One school-based clinic had a single PNP participate in the program (Table 2). For the control practices the number of study participants ranged from 1 to 3 providers/practice with 7 of the 8 practices having

1 to 2 MDs (6 practices) or 1 PNP (1 practice) and 1 to 2 MAs (7 practices) enrolled in the study. The control arm also included one school-based clinic with a single PNP participating in the study (Table 2). The intervention practice in pair #2 lacked a valid baseline quality estimate (Table 3), so its three-month run-in period was used instead.

SPIROMETRY FREQUENCY

During the study, participating practices uploaded 1,028 spirometry sessions to the database (279 during the 3-month run-in period, 164 during the 2-month baseline period, 585 during the 7-month intervention period). No significant difference was found between the intervention and control arms in the number of spirometry tests performed (treatment effect = -0.27, 95% confidence interval [95% CI] -2.86, 3.74; $P = .89$). When the 3 practices with counts of 0 or 1 spirometry tests (Table 3) were excluded as a sensitivity analysis, the difference remained non-significant ($P = .81$).

SPIROMETRY QUALITY

Simple binomial tests indicated that intervention practices had a significantly greater percentage of acceptable quality spirometry sessions compared with control practices (ATS grades of A or B; 45.5% vs 15.0%, difference = 30.5%, 95% CI 23.1%–37.8%, $P < .001$).

Some intervention practices had better performance in the percentage of acceptable quality spirometry sessions during the baseline period before the intervention (Table 3). After controlling for baseline performance, mixed-effects regression analysis indicated that intervention practices had a significantly greater odds of perform-

Table 2. Practice Characteristics

Characteristics	Number of Practice Pairs	
Practice characteristic		
Percent Medicaid insured		
5%–20%	3	
60%–100%	4	
Practice location		
Urban	5	
Suburban	1	
Rural	1	
Practice size		
Solo	2	
Mid-sized (3–6 providers)	3	
Large (7–10 providers	2	
Practice type		
Private practice	3	
Hospital-based clinic	2	
School-based clinic	1	
Public clinic	1	
Provider characteristics		
Provider type*	Intervention practices	Control practices
MD	9	7
MA/RN	10	10
PNP	2	2

*MD = Medical Doctor; MA/RN = Medical Assistant/Registered Nurse; PNP = Pediatric Nurse Practitioner.

ing acceptable quality spirometry testing sessions compared with control group practices (odds ratio [OR] 2.85, 95% CI 1.78–4.56, $P < .001$) during the intervention period. Baseline performance was significantly associated with percentage of acceptable quality testing sessions during the intervention period (OR 4.14, $P < .001$). For the sensitivity analysis, we ran a linear mixed effects model on passing proportions after excluding practices with 0 or 1 submission. On average, the intervention arm had a 19% greater proportion of acceptable quality testing sessions compared to the control arm ($P = .03$).

MEDICAL RECORDS DATA ANALYSIS

Four of the 7 matched pairs of practices submitted a total of 270 medical records for review (135 per arm). From these, we abstracted 414 eligible encounters for controls and 515 for intervention practices.

DOCUMENTATION OF ASTHMA SEVERITY

Intervention practices increased from documenting severity in 23% of cases in the baseline period (53/228 cases) to documenting it in 35% of cases during the 7-month intervention (99/287 cases). After adjusting for baseline performance, the intervention practices had a 2.9 times greater odds of documenting severity compared with control practices during the intervention period (OR 2.9, 95% CI 1.8–4.5; $P < .001$).

APPROPRIATE USE OF CONTROLLER MEDICATIONS

Both control and intervention practices prescribed controller medications appropriately for a majority of children with documented persistent asthma in both the baseline and intervention periods. In the 10-month preintervention period, among 109 encounters with severity documentation, persistent asthma occurred in 53.5% (30/56) of control encounters and in 43.3% (23/53) of intervention encounters. In these cases, controller medications were prescribed in 87% of control encounters and 100% of intervention encounters ($P = .21$).

During the intervention period, among 135 encounters with asthma severity documentation, persistent asthma occurred in 50% (18/36) of control encounters and in 61.6% (61/99) of intervention encounters. In 100% of control and 92% of intervention encounters, controller medications were appropriately prescribed ($P = .58$). Thus, although use of controller medications among persistent asthma patients displayed a "ceiling effect" with both groups, labeling of severity occurred significantly more often among intervention encounters. Because we lacked variability in controller use among patients with documented persistent asthma, we could not conduct a multivariate analysis to examine intervention effects on appropriate use of controller medications.

DISCUSSION

We successfully delivered a multifaceted spirometry distance-training program from Seattle, Washington, and

Table 3. Number of Spirometry Tests Performed and Percentage of Testing Sessions with Acceptable Quality by Study Period and Study Group for each Matched Practice Pair

Period	Matched Practice Pair	Number of Spirometry Tests Performed and Transmitted		Number and Percentage of Spirometry Testing Sessions with Acceptable Quality (%)	
		Control	Intervention	Control	Intervention
Run-in (months 1–3)	1	44	82	8 (18.2)	51 (62.2)
	2	3	6	2 (66.7)	3 (50)
	3	25	19	13 (52)	12 (63.2)
	4	7	8	2 (28.6)	3 (37.5)
	5	4	3	0 (0)	0 (0)
	6	36	19	12 (33.3)	0 (0)
	7	10	12	2 (20)	2 (15.4)
	Total	129	150	39 (30.2)	71 (47.3)
Baseline (months 4–5)	1	20	52	2 (10)	27 (51.9)
	2	5	0	3 (60)	0 (NA*)
	3	10	6	4 (40)	2 (33.3)
	4	0	17	0 (NA)	8 (47.1)
	5	24	1	2 (8.3)	0 (0)
	6	12	8	3 (25)	0 (0)
	7	4	5	0 (0)	0 (0)
	Total	75	89	14 (18.7)	37 (41.6)
Intervention Period (months 6–12)	1	169	123	9 (5.3)	70 (56.9)
	2	5	8	1 (20)	3 (37.5)
	3	78	49	25 (32.1)	25 (51.0)
	4	1†	34	1 (100)	20 (58.8)
	5	3	60	0 (0)	17 (28.3)
	6	30	24	7 (23.3)	1 (4.2)
	7	0†	1†	0 (NA)	0 (0.0)
	Total	286	299	43 (15.0)	136 (45.5)
Total	1028	490	538	96 (19.6)	244 (45.4)

*NA indicates not applicable because no curves were submitted and thus valid quality estimates could not be calculated.

†These numbers covered the entire 7-month intervention period and may have questionable validity. They were included in the intention-to-treat analysis.

other faculty locations to seven pediatric practices in New York. The percentage of acceptable quality spirometry sessions performed among intervention practices increased significantly compared with controls. Other findings support the stated program aim: improving primary care management of children with asthma. During the 7-month QI program, intervention practices had a significantly greater odds of documenting an asthma severity assessment, which we demonstrated to have a high concordance with appropriate treatment.

Overall, differences were not significant in the frequency of spirometry testing between the intervention and control arms. We observed a decrease in the frequency of spirometry testing from June through August (months 10-12), presumably because of infrequent asthma visits during those months. The challenges of increasing spirometry frequency typically involve multiple changes in care process and patient flow to perform the procedure during a planned (nonacute) visit, which may not have occurred during the study period. Improving spirometry quality, on the other hand, involves a focused effort on improving a specific skill set to optimize patient performance of the forced expiratory maneuver. In our opinion, a minimum frequency of 10 spirometry tests per month and an acceptability rate of 70% or better should be attainable at a general pediatric practice that is supported with proper training and feedback. On the basis of our continued

experience with and refinements to this training, we believe these benchmarks are achievable. If the number of current or potential asthma patients aged 5 years and older in a general pediatric practice is considered, test frequency could be much higher.

STUDY LIMITATIONS

Although participants were advised accordingly, there was no way to verify whether the performance of submitted spirograms was limited to the individuals that were trained by the program. Use of the spirometer by individuals not participating in the training may have biased our results toward the null. The final months of data collection during the summer also may have diminished our ability to show differences between groups. Variable compliance with the spirometry uploading procedure potentially limited our ability to detect differences between groups as some practices failed to send data during the 7-month intervention period. For those practices, we do not know which had no spirometry activity during those months, and which simply did not upload their data.

Although the quality of spirometry improved significantly among the intervention group when compared to controls, an "acceptable" rate of 45.5% at the end of the intervention may itself prove unacceptable. This intervention lasted for only 7 months, and it is possible that additional improvements would occur during a longer period

with extended feedback. Our feedback turnaround interval of 4 to 8 weeks from the time of the test may have been too long, and limited its effectiveness to some degree. Greater feedback specificity regarding technique errors may also improve the rate of acceptable tests. Further understanding of the barriers and facilitators for on-line training, and for routinely performing high quality spirometry in the primary care setting, is essential.

Contextual factors that may have influenced an intervention practice's ability to implement routine spirometry testing include staff turnover, lack of a planned visit structure and inability to incorporate spirometry testing into existing work-flow, and lack of practice leadership to encourage sustained use of spirometry. Understanding the relative contribution of these factors will be essential to the success of future practice-based QI programs.

CONCLUSIONS

A multifaceted distance QI training and feedback program resulted in increased spirometry quality and improved assessment of asthma severity levels. Successful participation in QI programs focused on procedures such as spirometry can occur over distance.

IMPLICATIONS OF FINDINGS

Incorporating spirometry into primary care enables another goal of the EPR-3 guidelines: promoting the use of periodic planned visits for the ongoing management of asthma, when otherwise undetected lung obstruction is most likely to be identified with spirometry. At a planned visit, lung function can be considered in the context of recent symptom frequency and unscheduled service use (emergency department visits and hospitalizations), which together comprise the elements of assessment for both asthma severity and control, according to guidelines.

Without training, however, spirometry in primary care is generally of low quality. A mechanism to train and certify those using spirometry has only recently been recommended.[26] Two-thirds of pediatric primary care physicians recently reported a desire for additional training to implement spirometry in clinical practice.[12] Generalized uptake of the National Asthma Education and Prevention Program guidelines for spirometry would require a major training initiative addressing the common barriers of pediatric primary care providers. Distance training and feedback programs as reported here provide one approach to this increasingly recognized shortcoming in asthma care.

This study demonstrated that the use of internet-based and visually rich multimedia tutorials, interactive case-based practice, and customized procedural feedback should be applicable to other clinical situations in which visual recognition and procedural learning are required. The continual spread of the internet and improvement of its related technologies make such remote interactive learning increasingly possible, a trend which can only be expected to increase in future years.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at doi:10.1016/j.acap.2011.11.006.

REFERENCES

1. Expert Panel Report 3 (EPR-3). Guidelines for the Diagnosis and Management of Asthma-Summary Report 2007. *J Allergy Clin Immunol*. 2007;120(suppl 5):S94–138.
2. Nair SJ, Daigle KL, DeCuir P, et al. The influence of pulmonary function testing on the management of asthma in children. *J Pediatr*. 2005;147:797–801.
3. Stout JW, Visness CM, Enright P, et al. Classification of asthma severity in children: the contribution of pulmonary function testing. *Arch Pediatr Adolesc Med*. 2006;160:844–850.
4. Wolfenden LL, Diette GB, Krishnan JA, et al. Lower physician estimate of underlying asthma severity leads to undertreatment. *Arch Intern Med*. 2003;163:231–236.
5. Baker JW, Mellon M, Wald J, et al. A multiple-dosing, placebo-controlled study of budesonide inhalation suspension given once or twice daily for treatment of persistent asthma in young children and infants. *Pediatrics*. 1999;103:414–421.
6. Sears MR. Increasing asthma mortality—fact or artifact? *J Allergy Clin Immunol*. 1988;82:957–960.
7. Suissa S, Ernst P, Benayoun S, et al. Low-dose inhaled corticosteroids and the prevention of death from asthma. *N Engl J Med*. 2000;343:332–336.
8. Adams RJ, Fuhlbrigge A, Finkelstein JA, et al. Impact of inhaled anti-inflammatory therapy on hospitalization and emergency department visits for children with asthma. *Pediatrics*. 2001;107:706–711.
9. Buxton MJ, Sullivan SD, Andersson LF, et al. Country-specific cost-effectiveness of early intervention with budesonide in mild asthma. *Eur Respir J*. 2004;24:568–574.
10. Weiss K, Buxton M, Andersson FL, et al. Cost-effectiveness of early intervention with once-daily budesonide in children with mild persistent asthma: results from the START study. *Pediatr Allergy Immunol*. 2006;17(suppl 17):21–27.
11. Legorreta AP, Christian-Herman J, O'Connor RD, et al. Compliance with national asthma management guidelines and specialty care: a health maintenance organization experience. *Arch Intern Med*. 1998;158:457–464.
12. Dombkowski KJ, Hassan F, Wasilevich EA, et al. Spirometry use among pediatric primary care physicians. *Pediatrics*. 2010;126:682–687.
13. Eaton T, Withy S, Garrett JE, et al. Spirometry in primary care practice: the importance of quality assurance and the impact of spirometry workshops. *Chest*. 1999;116:416–423.
14. Ferguson GT, Enright PL, Buist AS, et al. Office spirometry for lung health assessment in adults: a consensus statement from the National Lung Health Education Program. *Chest*. 2000;117:1146–1161.
15. Bunik M, Fredrico MJ, Beaty B, et al. Quality improvement for asthma care within a hospital teaching clinic. *Acad Pediatr*. 2011;11:58–65.
16. Mandel KE, Kotagal UR. Pay for performance alone cannot drive quality. *Arch Pediatr Adolesc Med*. 2007;161:650–655.

17. Boushon B, Provost L, Gagnon J, et al. Using a virtual breakthrough series collaborative to improve access in primary care. *Jt Comm J Qual Improv*. 2006;32:573–584.

18. Powell H, Stout JW. *Spirometry Fundamentals: A Basic Guide to Lung Function Testing (CD-ROM). Version 1.2*. Seattle, Wash: University of Washington; 2006.

19. Cisco WebEx. Available at: http://www.webex.com. Accessed October 26, 2011.

20. University of Washingtion, integrated Medical Training Resources. Our Programs. Spirometry training. Available at: http://www.spirometrytraining.org. Accessed October 26, 2011.

21. Fleiss J, Levin B, Cho Paik M. *Statistical Methods for Rates and Proportions*. 3rd ed. New York, NY: John Wiley & Sons; 2003.

22. National Heart, Lung, and Blood Institute. Expert Panel Report: Guidelines for the Diagnosis and Management of Asthma-Update on Selected Topics; 2002. Available at: http://www.nhlbi.nih.gov/guidelines/archives/epr-2_upd/index.htm. Accessed January 11, 2012.

23. Pinheiro J, Bates D. *Mixed-Effects Models in S and S-Plus*. New York, NY: Springer Verlag; 2000.

24. R Development Core Team. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. Available at, http://www.R-project.org/; 2011.

25. StatCorp. *Stata statistical software: Release 12*. College Station, Tex: StataCorp LP; 2011.

26. Levy M, Quanjer P, Booker R, et al. Diagnostic spirometry in primary care: proposed standards for general practice compliant with American Thoracic Society and European Respiratory Society recommendations. *Primary Care Respir J*. 2009;18:130–147.