Informatics in Primary Care 2009;17:231–40

Refereed paper

Documentation-based clinical decision support to improve antibiotic prescribing for acute respiratory infections in primary care: a cluster randomised controlled trial

Jeffrey A Linder MD MPH FACP
Division of General Medicine and Primary Care, Brigham and Women's Hospital and Harvard Medical School, USA

Jeffrey L Schnipper MD MPH
Division of General Medicine and Primary Care, Brigham and Women's Hospital and Harvard Medical School, USA

Ruslana Tsurikova MA MSc
Division of General Medicine and Primary Care, Brigham and Women's Hospital and Clinical Informatics Research and Development, Partners HealthCare System, USA

Tony Yu MD MPH
Division of General Medicine and Primary Care, Brigham and Women's Hospital and Clinical and Quality Analysis, Partners HealthCare System, USA

Lynn A Volk MHS
Clinical and Quality Analysis, Partners HealthCare System, USA

Andrea J Melnikas MPH
The Population Council, USA

Matvey B Palchuk MD MS
Recombinant Data Corp and Harvard Medical School, USA

Maya Olsha-Yehiav MS
Clinical Informatics Research and Development, Partners HealthCare System, USA

Blackford Middleton MD MPH MSc FACP FACMI FHIMSS
Division of General Medicine and Primary Care, Brigham and Women's Hospital, Harvard Medical School and Clinical Informatics Research and Development, Partners HealthCare System, USA

ABSTRACT

Background and objective Clinical guidelines discourage antibiotic prescribing for many acute respiratory infections (ARIs), especially for non-antibiotic appropriate diagnoses. Electronic health record (EHR)-based clinical decision support has the potential to improve antibiotic prescribing for ARIs.

Methods We randomly assigned 27 primary care clinics to receive an EHR-integrated, documentation-based clinical decision support system for the care of patients with ARIs – the *ARI Smart Form* – or to offer usual care. The primary outcome was the antibiotic prescribing rate for ARIs in an intent-to-intervene analysis based on administrative diagnoses.

Results During the intervention period, patients made 21 961 ARI visits to study clinics. Intervention clinicians used the *ARI Smart Form* in 6% of 11 954 ARI visits. The antibiotic prescribing rate in the intervention clinics was 39% versus 43% in the control clinics (odds ratio (OR), 0.8; 95% confidence interval (CI), 0.6–1.2, adjusted for clustering by clinic). For antibiotic appropriate ARI diagnoses, the antibiotic prescribing rate was 54% in the intervention clinics and 59% in the control clinics (OR, 0.8; 95% CI, 0.5–1.3). For non-antibiotic appropriate diagnoses, the antibiotic prescribing rate was 32% in the intervention clinics and 34% in the control clinics (OR, 0.9; 95% CI, 0.6–1.4). When the *ARI Smart Form* was used, based on diagnoses entered on the form, the antibiotic prescribing rate was 49% overall, 88% for antibiotic appropriate diagnoses and 27% for non-antibiotic appropriate diagnoses. In an as-used analysis, the *ARI Smart Form* was associated with a lower antibiotic prescribing rate for acute bronchitis (OR, 0.5; 95% CI, 0.3–0.8).

Conclusions The *ARI Smart Form* neither reduced overall antibiotic prescribing nor significantly improved the appropriateness of antibiotic prescribing for ARIs, but it was not widely used. When used, the *ARI Smart Form* may improve diagnostic accuracy compared to administrative diagnoses and may reduce antibiotic prescribing for certain diagnoses.

Keywords: antibacterial agents, computerised medical record systems, clinical decision support systems, respiratory tract infections

Introduction

Acute respiratory infections (ARIs) – including nonspecific upper respiratory infections, otitis media, sinusitis, pharyngitis, acute bronchitis, pneumonia and influenza – are the most common symptomatic reason for seeking ambulatory care in the USA, accounting for approximately 7% of visits.[1] ARIs are also the number one reason for antibiotic prescribing in the USA, accounting for about 50% of antibiotic prescriptions to adults.[2] Guidelines and reviews from the USA and internationally generally discourage antibiotic prescribing for ARIs,[3–8] but much antibiotic prescribing for ARIs is inappropriate due to prescribing antibiotics for viral conditions or prescribing unnecessarily broad-spectrum antibiotics.[9–11] Inappropriate antibiotic prescribing increases medical costs, increases the prevalence of antibiotic resistant bacteria, and needlessly exposes patients to adverse drug events.[12,13]

Electronic health records (EHRs) with clinical decision support have shown potential for improving the quality of medical care, mainly through the use of prescribing alerts and preventive care reminders.[14] Improving care for ARIs through decision support may be more challenging than for chronic problems, because the quality problem is an error of commission, decision support must be delivered during patient visits and ARI visits are typically brief.[15,16]

We designed an EHR-integrated, documentation-based clinical decision support system for the care of patients with ARIs, the *ARI Smart Form*. We designed the *ARI Smart Form* with two principal objectives: to assist clinicians in reducing inappropriate antibiotic prescribing and to improve workflow for clinicians. We have previously reported results of usability testing and pilot testing, which showed the potential of the *ARI Smart Form* to be incorporated into clinical practice and reduce inappropriate antibiotic prescribing.[17,18] To evaluate the *ARI Smart Form* in actual practice, we conducted a cluster randomised controlled trial in primary care clinics.

Methods

Setting and EHR

Partners HealthCare System is an integrated regional healthcare delivery system in eastern Massachusetts. The main EHR used in Partners HealthCare ambulatory clinics is the longitudinal medical record, or LMR. The LMR is an internally developed, full featured EHR, approved by the Certification Commission for Healthcare Information Technology and including; primary care and subspecialty notes; problem lists; medication lists; coded allergies; and laboratory test and radiographic study results.[19]

The *ARI Smart Form*

The *ARI Smart Form* has been described previously.[17,18] Briefly, the *ARI Smart Form* is an LMR module that is launched from the notes page of the EHR and is designed to be used while interviewing and evaluating patients. The *ARI Smart Form* includes six components: entry of clinical information; patient data display; diagnosis selection; presentation of treatment options with integrated decision support; printing of patient handouts and access to supporting medical literature. The *ARI Smart Form* imports patients' problem lists, allergies, medications and vital signs into the visit note; speeds workflow using drop-down lists, radio buttons and check boxes; and provides 'one-click' ordering of medicines, patient handouts, and excuse-from-work letters. The *ARI Smart Form* automatically generates a narrative visit note that would usually meet Evaluation and Management criteria for a Level 4 visit (moderate severity on a one to five scale).

The *ARI Smart Form* provides decision support in several ways. First, clinicians' selection of a particular ARI diagnosis results in the generation of a diagnosis appropriate order set. Antibiotic prescribing and antibiotic choices are based on the recommendations of the Centers for Disease Control and Prevention (CDC) and the American College of Physicians (ACP).[8] At a basic level, the *ARI Smart Form* decision support strives to make the antibiotic treatment match the diagnosis (e.g. not prescribing antibiotics for patients with acute bronchitis). Second, the *ARI Smart Form* provides diagnostic decision support by calculating the probability of streptococcal pharyngitis based on signs and symptoms entered by the clinician, and also how rapid streptococcal testing will change the probability of streptococcal pharyngitis.[20] Third, the *ARI Smart Form* has medication prescribing alerts regarding potential medication interactions or patient allergies. Fourth, the *ARI Smart Form* supports clinicians by providing easy access to diagnosis appropriate patient handouts. The handouts contain information about the diagnosis and why antibiotics may or may not be indicated. Mainly through the use of diagnosis appropriate order sets, we strove to make it easy for clinicians to follow ARI antibiotic prescribing guidelines.[21]

Clinic matching and randomisation

We randomly assigned 27 primary care clinics associated with Partners HealthCare that use the LMR to participate in the study. With the exception of a single clinic that was randomly assigned on its own, clinics were matched on the basis of size. Matched pairs were randomised simultaneously, with one practice from each pair assigned to receive the intervention and the other assigned to offer usual care.

Intervention and implementation

The intervention period was from 3 November 2005 to 31 May 2006. The lead co-investigator (JAL) visited each of the 13 intervention clinics once for up to an hour at the beginning of the intervention period to introduce and describe the *ARI Smart Form* to clinicians. Clinicians had access to an online RoboDemo™ introduction to the *ARI Smart Form* functionality. Throughout the intervention period, monthly emails were sent to intervention clinics reminding clinicians about the *ARI Smart Form* and providing summary *ARI Smart Form* usage counts at each clinic, compared to other clinics. The Human Research Committee of Partners HealthCare approved the study protocol.

Outcomes

The primary outcome was the antibiotic prescribing rate for ARI visits, based on electronic prescribing using the EHR, using an intent-to-intervene analysis. We had previously found that EHR based antibiotic prescribing had a sensitivity of 43%, but was increasing rapidly over time, from 22% in 2000 to 58% in 2003.[22] During the intervention period, it was the policy of study clinics that all prescriptions be written using the EHR. We defined antibiotic use as the prescription of an orally administered antibiotic agent within three days of an ARI visit. Secondary outcomes included antibiotic prescribing for antibiotic appropriate diagnoses, non-antibiotic appropriate diagnoses and individual ARI diagnoses; the 30-day revisit rate; and the 30-day revisit rate attributable to ARIs (i.e. a second visit within 30 days of the index ARI visit with another ARI diagnosis). We also performed as-used analyses, comparing antibiotic prescribing rates in clinic visits in which the *ARI Smart Form* was used to visits in the control clinics.

Data collection and analysis

We examined baseline characteristics of the control and intervention clinics and clinicians. We identified ARI visits using administrative data coded using the International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM) codes. ARI visits were those with any ICD-9-CM code for non-specific upper respiratory infections (ICD-9-CM 460, 464 and 465), otitis media (ICD-9-CM 381 and 382), sinusitis (ICD-9-CM 461 and 473), pharyngitis (streptococcal and non-streptococcal; ICD-9-CM 034.0, 462 and 463), acute bronchitis (ICD-9-CM 466 and 490), influenza (ICD-9-CM 487) and pneumonia (ICD-9-CM 481–486). These administrative data have a sensitivity of 98%, specificity of 96% and positive predictive value of 96% compared with medical record review.[22] We considered otitis media, sinusitis, streptococcal pharyngitis, and pneumonia to be antibiotic appropriate diagnoses. We considered non-specific upper respiratory tract infections, non-streptococcal pharyngitis, acute bronchitis and influenza to be non-antibiotic appropriate diagnoses.

During the intervention, we measured the number of visits, the number of ARI visits and, for clinicians in the intervention practices, whether clinicians ever used the *ARI Smart Form*. Using registration data, we examined patient age, gender, race/ethnicity, primary language, primary insurance and mean income by zip code. For intervention visits at which the *ARI Smart Form* was used, we recorded the duration of use (i.e. the amount of time between opening and submitting the *ARI Smart Form*).

Statistical analysis and power calculation

We used standard descriptive statistics to compare clinicians and patients. To account for the level of randomisation, we adjusted all statistical analyses – the chi-squared test for categorical variables and Student's *t*-test for continuous variables – for clustering by practice using PROC GENMOD in SAS version 9.1 (SAS Institute Inc., Cary, NC). For visits in which the *ARI Smart Form* was used, we used chance-corrected k with 95% confidence intervals to assess the degree of agreement between the ICD-9 diagnosis and the *ARI Smart Form* listed diagnosis.[23] We considered two-sided P values < 0.05 significant. Assuming a baseline antibiotic prescribing rate for ARIs of 35%, α of 0.05 and an intra-class correlation coefficient of 0.10, 1798 visits in each group were required to have 80% power to detect a 7% absolute reduction in the antibiotic prescribing rate.[22]

Results

Clinic, clinician and patient characteristics

Prior to the intervention, there were no differences between the intervention and control clinics in duration of EHR use, overall antibiotic prescribing rates or ARI antibiotic prescribing rates (data not shown). During the seven-month intervention period, there were 214 900 visits by 111 820 patients to 443 clinicians in the 27 control and intervention practices (Figure 1). There were no significant differences in the clinicians or the patients between the control and intervention clinics (Table 1 and Table 2). There was no difference in the ARI visit rate between control clinics (10% (10 007/98 894)) and intervention clinics (10% (11 954/116 006); $P = 0.89$).

ARI Smart Form use

In intervention clinics, 33% (86/262) of clinicians used the *ARI Smart Form* at least once (Table 1). Based on ICD-9 codes, the *ARI Smart Form* was used in 6% (742/11 954) of ARI visits (Table 3). For intervention ARI visits at which the *ARI Smart Form* was used, the duration of form use was 8.1 (standard deviation, 5.8) minutes.

Antibiotic prescribing

In the intent-to-intervene analysis, clinicians prescribed antibiotics to 43% of patients with ARI diagnoses in control clinics and to 39% of patients with ARI diagnoses in intervention clinics (OR, 0.8; 95% CI, 0.6–1.2; $P = 0.30$; Table 3). There was no significant difference in antibiotic prescribing for antibiotic appropriate ARIs (OR, 0.8; 95% CI, 0.5–1.3) or for non-antibiotic appropriate ARIs (OR, 0.9; 95% CI, 0.6–1.4). There was also no significant difference in antibiotic prescribing between control and intervention clinics for non-ARI visits (5% in control clinics versus 6% in intervention clinics; OR, 1.1; 95% CI, 0.9–1.3) or for all visits (9% in both control and intervention clinics; OR, 1.0; 95% CI, 0.8–1.2).

In the as-used analysis, for visits in which the *ARI Smart Form* was used (n = 990), there was good

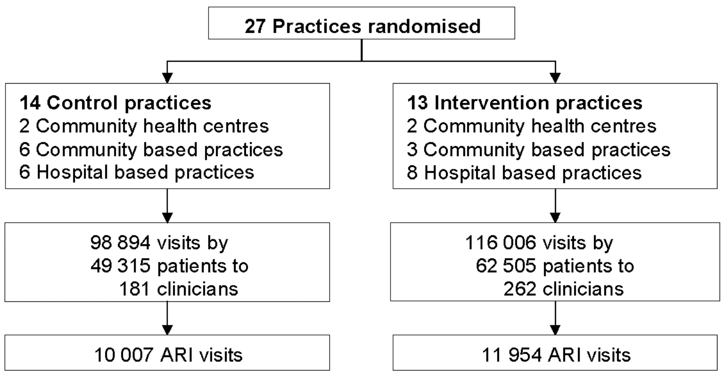

Figure 1 Randomisation

Table 1 Clinician characteristics

Characteristic	Control (n = 181)	Intervention (n = 262)	P value[a]
Age, years (SD)[b]	39 (11)	39 (12)	0.74
Type of clinician, n (%)			0.11
Staff physician	98 (54)	115 (44)	
Fellow	4 (2)	14 (5)	
Resident	66 (36)	105 (40)	
NP or PA[c]	8 (4)	23 (9)	
Other	5 (3)	5 (2)	
Female, n (%)	115 (64)	143 (55)	0.12
Experienced with EHR, %[d]	78	71	0.23
Visits during intervention period, mean	546	443	0.45
ARI visits, mean[e]	55	46	0.52
At least one ARI visit, n (%)	172 (95)	248 (95)	0.84
Clinicians who submitted at least one *ARI Smart Form*, n (%)	NA[f]	86 (33)	NA

[a] P values adjusted for clustering by clinic, except for 'experience with EHR'
[b] SD, standard deviation
[c] NP, nurse practitioner; PA, physician assistant
[d] EHR, electronic health record. In the control group, 62 of 79 respondents said they were 'somewhat experienced' or 'very experienced' at using the electronic health record in a pre-intervention survey. In the intervention group, 80 of 113 respondents said they were 'somewhat experienced' or 'very experienced' at using the electronic health record.
[e] ARI, acute respiratory infection
[f] NA, not applicable

agreement between the ICD-9 diagnosis and the *ARI Smart Form* listed diagnosis (k, 0.54; 95% CI, 0.50–0.58). In the as-used analysis with diagnoses derived from the *ARI Smart Form*, antibiotic prescribing rates were 88% for antibiotic appropriate diagnoses (compared with 59% in control visits; OR, 5.0; 95% CI, 2.9–8.6), 27% for non-antibiotic appropriate diagnoses (compared with 34%; OR, 0.7; 95% CI, 0.5–1.0) and 49% for all ARI diagnoses (compared with 43%; OR, 1.3; 95% CI, 0.8–2.0). In the as-used analysis, the antibiotic prescribing rate was lower for acute bronchitis (45% vs 61%, OR, 0.5 compared to control clinics; 95% CI, 0.3–0.8).

Revisit rates

The 30-day revisit rate to study clinics for control ARI visits was 26% (2566/10 007) and for intervention visits was 23% (2765/11 954; P = 0.32). The 30-day revisit rate to study clinics attributable to ARIs was 9% (913/10 007) in control clinics and 8% (969/11 954) in intervention clinics (P = 0.29).

Discussion

We evaluated the *ARI Smart Form*, a documentation-based clinical decision support system, in a cluster randomised controlled trial. The point estimates for antibiotic prescribing for all ARI diagnoses, antibiotic appropriate ARI diagnoses and non-antibiotic appropriate ARI diagnoses were less than 1.0. As used, the *ARI Smart Form* was associated with a marginal reduction in antibiotic prescribing for non-antibiotic appropriate diagnoses and a reduction in antibiotic prescribing for acute bronchitis, one of two diagnoses that account for the majority of ARI antibiotic prescribing.[2] However, these findings were either not statistically significant or were subgroup analyses that may not generalise to the entire population making

Table 2 Patient characteristics

Characteristic	Control (n = 49 315)	Intervention (n = 62 505)	*P* value[a]
Clinic visits per patient in the last three years, mean (SD)	6.0 (6.4)	5.0 (5.4)	0.22
Age, mean years (SD)[b]	48 (17)	49 (17)	0.97
Female, *n* (%)	33 768 (69)	38 281 (61)	0.22
Race and ethnicity, *n* (%)			0.66
White	28 469 (58)	30 265 (48)	
Latino	4327 (9)	11 331 (18)	
Black	3660 (7)	5722 (9)	
Other or unknown	12 859 (26)	15 187 (24)	
Language, *n* (%)			0.55
English	42 092 (85)	48 361 (77)	
Spanish	3411 (7)	9175 (15)	
Other	3812 (8)	4969 (8)	
Primary insurance, *n* (%)			0.95
HMO[c]	14 697 (30)	16 447 (26)	
Private	17 511 (36)	20 025 (32)	
Medicare	7975 (16)	10 543 (17)	
Medicaid	3877 (8)	6128 (10)	
Free care	1995 (4)	3996 (6)	
Self-pay	1400 (4)	2624 (4)	
Other	1860 (4)	2742 (4)	
Income by zip code, mean $ (SD)	63 113 (37 063)	62 182 (40 239)	0.88

[a] *P* values adjusted for clustering by clinic
[b] SD, standard deviation
[c] HMO, health maintenance organisation

ARI visits. In the primary intent-to-intervene analysis, the *ARI Smart Form* was not associated with improved antibiotic prescribing for ARIs overall. The main reason for this finding was the poor uptake of the *ARI Smart Form*.

We designed the *ARI Smart Form* to have self-evident value to clinicians. It was our hope that it would effectively facilitate documentation, improve workflow and provide integrated decision support. We designed the *ARI Smart Form* to include three of the four clinical decision support characteristics associated with improved clinical practice: provision of recommendations rather than just assessments; provision of decision support at the time and location of decision making; and computer-based decision support.[24] Why then was the *ARI Smart Form* used in so few visits?

First, we were missing the fourth characteristic of successful clinical decision support applications: the automatic provision of decision support as part of clinicians' workflow.[24] Clinicians had to actively invoke the *ARI Smart Form* from the notes page. Such voluntarily invoked applications may go unused, in part because clinicians do not think they need decision support.[25] Second, the *ARI Smart Form* may not have felt sufficiently integrated with the rest of the EHR. The *ARI Smart Form*, when invoked, appeared in a separate window, unlike other methods of documentation within the EHR. To be most effective, clinical decision support must fit as seamlessly as possible into existing workflow and allow clinicians to manage unanticipated interruptions.[21,26]

Third, the *ARI Smart Form* introduced new concepts in documentation for our EHR: drop-down lists, check boxes, radio buttons and automatic generation of a narrative note. Clinicians may have been turned off by what they felt was new complexity that could lead to a loss of overview, fragmentation of thinking and an overly detailed and unhelpful resulting note,[26] especially for a medical problem generally perceived to be straightforward. Fourth, the *ARI Smart Form*

Table 3 Antibiotic prescribing by ARI diagnosis[a]

	Control		Intervention					
			Intent-to-intervene		*Smart Form* as used			
					ICD-9 codes[b]		Smart Form diagnosis	
	n	Antibiotic *n* (%)	*n*	Antibiotic *n* (%)	*n*	Antibiotic *n* (%)	*n*	Antibiotic *n* (%)
Antibiotic appropriate diagnoses								
Pneumonia	604	195 (32)	765	280 (37)	32	28 (88)	38	33 (87)
Streptococcal pharyngitis	123	75 (61)	65	47 (72)	9	9 (100)	75	69 (92)
Sinusitis	2457	1587 (65)	2294	1310 (57)	164	143 (87)	191	167 (87)
Otitis media	587	351 (60)	612	363 (59)	32	25 (78)	41	33 (81)
Sub-total	**3771**	**2208 (59)**	**3736**	**2000 (54)**	**237**	**205 (87)**	**345**	**302 (88)**
Non-antibiotic appropriate diagnoses								
Non-streptococcal pharyngitis	2176	726 (33)	2771	857 (31)	165	86 (52)	56	11 (20)
Influenza	54	6 (11)	204	21 (10)	10	0 (0)	81	13 (16)
Acute bronchitis	1433	875 (61)	1649	833 (51)	100	53 (53)	221	99 (45)
Non-specific URI	2573	501 (19)	3594	890 (25)	230	35 (15)	236	36 (15)
Sub-total	**6236**	**2108 (34)**	**8218**	**2601 (32)**	**505**	**174 (35)**	**594**	**159 (27)**
ARI visits[c]	10 007	4316 (43)	11 954	4601 (39)	742	379 (51)	939	461 (49)
Non-ARI visits	88 887	4727 (5)	104 052	5957 (6)	248[d]	97 (39)	51[e]	15 (29)
Total visits	98 894		116 006		990		990	

[a] ARI, acute respiratory infection
[b] ICD-9 – International Classification of Diseases, 9th Edition, Clinical Modification
[c] The primary outcome was the intent-to-intervene analysed difference in antibiotic prescribing between control and intervention practices for acute respiratory infection visits in aggregate, adjusted for clustering by clinic (odds ratio, 0.8; 95% confidence interval, 0.6–1.2; $P = 0.30$)
[d] The most common diagnoses for these 248 visits were cough (36%), no diagnosis given (29%), unspecified viral infection (10%), allergic rhinitis (4%) and asthma (2%)
[e] The most common diagnoses for these 51 visits were other diagnoses (31%), allergies (25%), cough (19%) and asthma (12%)

introduced a lack of flexibility. Clinicians needed to make a determination at the beginning of the visit or the beginning of documentation whether or not they were going to use the *ARI Smart Form*. Clinicians may have feared being 'locked-in' to using the *ARI Smart Form* when they were unsure whether the visit would include other problems.[26] Finally, some clinicians – our prior work would suggest about 25% – may not use the EHR at all during patient visits.[27]

Even as-used, the *ARI Smart Form* was only associated with, at best, modest improvements in diagnostic accuracy and antibiotic prescribing. *ARI Smart Form* use was also associated with increased antibiotic prescribing for antibiotic appropriate diagnoses. Whether these results are due to more appropriate prescribing, better matching of diagnosis to treatment, or both is not clear. Why was the *ARI Smart Form*, as-used, not effective in reducing the antibiotic prescribing rate?

First, there is the usual list of reasons that clinicians cite for prescribing antibiotics for predominantly viral ARIs – diagnostic uncertainty, lack of time, patient desire and fear of complications, among others – and a lack of compelling reasons for clinicians to change practice patterns.[13,28,29] Second, contributing to diagnostic and therapeutic uncertainty, there are competing and conflicting guidelines for some ARIs.[30] Third, providers may be concerned that the recommendations will not be applicable to their patients or will not be tolerated (i.e. because of comorbidities or contraindications).[31] Fourth, clinicians may have preferentially used the *ARI Smart Form* when they were going to prescribe antibiotics. Finally, there may be particular challenges to providing decision support for acute problems and errors of commission. Most decision support applications for ambulatory care have addressed errors of omission for chronic problems.[24,32] It may be inherently more difficult to provide decision support that strives to have clinicians *not* do something in the context of a single visit than to encourage clinicians to take an action over time for a chronic problem.[21]

There have been many other examples of clinical decision support implementation failures reported in the medical literature. These failures have included order entry decision support for hypertension, congestive heart failure, coronary artery disease, asthma and chronic obstructive pulmonary disease;[31,33–36] an EHR based clinical decision support system for the management of asthma and angina in primary care;[37,38] a computer clinical decision support system to reduce cardiovascular risk for patients with hypertension;[39] and reminders for the care of chronic conditions.[40,41]

For all these failures, Samore and colleagues had notable success with introducing paper and personal digital assistant based clinical decision support to rural communities to increase the appropriateness of antibiotic prescribing for ARIs.[42] Communities that received clinical decision support had a reduction in antibiotic prescribing and clinicians in those communities reduced antibiotic prescribing for non-antibiotic appropriate diagnoses. The implementation by Samore and colleagues was extremely intensive: they reached 71% of clinicians in intervention communities; contacted pharmacies, mayors, health departments and school superintendents; and distributed thousands of posters, brochures and household mailings. This intensity of implementation was probably critical to its success.

In the future, other than the design issues addressed above, what steps could ensure that applications similar to the *ARI Smart Form* are used? First, the introduction and training should be more intensive. For this trial, the introduction of the *ARI Smart Form* was limited and weak. The lead investigator introduced the application with a single site visit at which only some of a practice's clinicians were present. This visit was followed with monthly emails to all intervention providers, but the application was not formally supported. A single visit and seven emails is probably not enough to encourage users to try a new application intended for use during patient visits. Broad programmatic support with a phased roll-out, with more intensive introduction and training at each clinic, may have been more successful.[43] Second, with such a limited and weak introduction strategy, the seven-month intervention period may not have allowed enough time for knowledge of the application to have diffused through the intervention clinics. Since the end of the study, with no promotion, the *ARI Smart Form* has been available throughout the Partners HealthCare system. From June 2006 to February 2009, over 450 clinicians used the *ARI Smart Form* 13 435 times and a newer paediatric version of the *ARI Smart Form* was used 2722 times by about 70 paediatricians. Clearly many clinicians – admittedly a minority – are finding some value in using the *ARI Smart Form*. Finally, our experience highlights the importance of ongoing cycles of usability testing and application refinement prior to widespread roll-out. Moving forward, we should go back to focus groups of users and non-users to find out more about what they did not like about the *ARI Smart Form* and make design changes. Qualitative research is critical to understanding how and why the *ARI Smart Form* went unused and if future modifications are worthwhile.[26,38]

Our study has several limitations that should be considered. First, our identification of ARI visits was dependent on claims diagnoses. We had previously found that claims diagnoses for ARIs were accurate,[22] but there was probably some degree of diagnostic misclassification. This is apparent in examining specific ARI diagnoses in the as-used intervention group when the diagnosis was determined using ICD-9-CM codes or the *ARI Smart Form* diagnosis. This also reveals another potential benefit of applications like the *ARI Smart Form* – improvement in documentation and coding. Second, we identified antibiotic prescribing only using the EHR. Prescriptions that were hand-written or phoned-in without EHR entry or that occurred outside the context of a visit could be missed, but we would expect this to be increasingly rare in the Partners HealthCare system.[22] Finally, the trial was conducted in academically affiliated primary care clinics using a locally developed system, possibly limiting the extent to which it can be generalised.

Conclusion

In conclusion, introduction of a documentation-based clinical decision support system for the care of patients with ARIs did not result in significant changes in antibiotic prescribing, primarily because the application went largely unused. Even as-used, the *ARI Smart Form* was not clearly associated with improved antibiotic prescribing. For similar applications, developers should ensure their applications are well integrated into workflow and significant resources are dedicated to implementation. To decrease inappropriate antibiotic prescribing for ARIs, many other strategies beyond clinician directed computerised clinical decision support can be employed: physician education, physician audit and feedback (including counter-detailing and use of opinion leaders), patient education, multi-dimensional interventions, delayed antimicrobial prescriptions and financial or regulatory incentives.[44–46] However, health information technology is likely to be part of the solution in improving quality. As ARIs are the primary reason for antibiotic prescribing, much of it inappropriate, there remains a need for scalable and effective technology interventions that decrease inappropriate antibiotic prescribing.

ACKNOWLEDGEMENTS

This study was supported by a grant from the Agency for Healthcare Research and Quality (1 R01 HS015169–01). Dr Linder was supported by a career development award (K08 HS014563) from the Agency for Healthcare Research and Quality. Dr Schnipper was supported by a mentored career development award from the National Heart, Lung and Blood Institute (1 K08 HL072806–01).

REFERENCES

1 Cherry DK, Hing E, Woodwell DA and Rechtsteiner EA. *National Ambulatory Medical Care Survey: 2006 summary.* National Health Statistics Reports; no. 3. Hyattsville, MD: National Center for Health Statistics, 2008.
2 Steinman MA, Gonzales R, Linder JA and Landefeld CS. Changing use of antibiotics in community-based outpatient practice, 1991–1999. *Annals of Internal Medicine* 2003;138:525–33.
3 Ahovuo-Saloranta A, Borisenko OV, Kovanen N *et al.* Antibiotics for acute maxillary sinusitis. *Cochrane Database of Systematic Reviews* 2009;4:CD000243.
4 Arroll B and Kenealy T. Antibiotics for the common cold and acute purulent rhinitis. *Cochrane Database of Systematic Reviews* 2009;4:CD000247.
5 Smith SM, Fahey T, Smucny J and Becker L. Antibiotics for acute bronchitis. *Cochrane Database of Systematic Reviews* 2009;4:CD000245.
6 Spinks A, Del Mar CB and Glasziou PP. Antibiotics for sore throat. *Cochrane Database of Systematic Reviews* 2009;4:CD000023.
7 NICE Short Clinical Guidelines Technical Team. *Respiratory tract infections – antibiotic prescribing. Prescribing of antibiotics for self-limiting respiratory tract infections in adults and children in primary care.* London: National Institute for Health and Clinical Excellence, 2008.
8 Gonzales R, Bartlett JG, Besser RE *et al.* Principles of appropriate antibiotic use for treatment of acute respiratory tract infections in adults: background, specific aims, and methods. *Annals of Internal Medicine* 2001; 134:479–86.
9 Steinman MA, Landefeld CS and Gonzales R. Predictors of broad-spectrum antibiotic prescribing for acute respiratory tract infections in adult primary care. *Journal of the American Medical Association* 2003;289:719–25.
10 Linder JA, Bates DW, Lee GM and Finkelstein JA. Antibiotic treatment of children with sore throat. *Journal of the American Medical Association* 2005;294:2315–22.
11 Linder JA and Stafford RS. Antibiotic treatment of adults with sore throat by community primary care physicians: a national survey, 1989–1999. *Journal of the American Medical Association* 2001;286:1181–6.
12 Shehab N, Patel PR, Srinivasan A and Budnitz DS. Emergency department visits for antibiotic-associated adverse events. *Clinical Infectious Diseases* 2008;47:735–43.
13 Linder JA. Antibiotics for treatment of acute respiratory tract infections: decreasing benefit, increasing risk, and the irrelevance of antimicrobial resistance. *Clinical Infectious Diseases* 2008;47:744–6.
14 Chaudhry B, Wang J, Wu S *et al.* Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. *Annals of Internal Medicine* 2006;144:742–52.
15 Linder JA. Health information technology as a tool to improve care for acute respiratory infections. *American Journal of Managed Care.* 2004;10:661–2.
16 Linder JA, Singer DE and Stafford RS. Association between antibiotic prescribing and visit duration in adults with upper respiratory tract infections. *Clinical Therapeutics* 2003;25:2419–30.
17 Linder JA, Rose AF, Palchuk MB *et al.* Decision support for acute problems: the role of the standardized patient in usability testing. *Journal of Biomedical Informatics* 2006;39:648–55.
18 Linder JA, Schnipper JL, Volk L *et al.* Clinical decision support to improve antibiotic prescribing for acute respiratory infections: results of a pilot study. *American Medical Informatics Assocation Annual Symposium Proceedings* 2007:468–72.
19 Certification Commission for Healthcare Information Technology. *Partners HealthCare System Longitudinal Medical Record (LMR) 5.1.1.* www.cchit.org/products/2006/ambulatory/1441. (accessed 8 December 2009).
20 Centor RM, Witherspoon JM, Dalton HP, Brody CE and Link K. The diagnosis of strep throat in adults in the emergency room. *Medical Decision Making* 1981;1:239–46.
21 Bates DW, Kuperman GJ, Wang S *et al.* Ten commandments for effective clinical decision support: making the practice of evidence-based medicine a reality. *Journal of the American Medical Informatics Association* 2003;10: 523–30.
22 Linder JA, Bates DW, Williams DH, Connolly MA and Middleton B. Acute infections in primary care: accuracy of electronic diagnoses and electronic antibiotic prescribing. *Journal of the American Medical Informatics Association* 2006;13:61–6.
23 Rosner B. *Fundamentals of Biostatistics* (5e). Pacific Grove, CA: Duxbury, Thomson Learning, 2000.
24 Kawamoto K, Houlihan CA, Balas EA and Lobach DF. Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. *British Medical Journal* 2005; 330:765.
25 Bobb AM, Payne TH and Gross PA. Viewpoint: controversies surrounding use of order sets for clinical decision support in computerized provider order entry. *Journal of the American Medical Informatics Association* 2007; 14:41–7.
26 Ash JS, Berg M and Coiera E. Some unintended consequences of information technology in health care: the nature of patient care information system-related errors. *Journal of the American Medical Informatics Association* 2004;11:104–12.

27 Linder JA, Schnipper JL, Tsurikova R, Melnikas AJ, Volk LA and Middleton B. Barriers to electronic health record use during patient visits. *American Medical Informatics Association Annual Symposium Proceedings* 2006:499–503.
28 Linder JA. Improving care for acute respiratory infections: better systems, not better microbiology. *Clinical Infectious Diseases* 2007;45:1189–91.
29 Linder JA, Ma J, Bates DW, Middleton B and Stafford RS. Electronic health record use and the quality of ambulatory care in the USA. *Archives of Internal Medicine* 2007;167:1400–5.
30 Linder JA, Chan JC and Bates DW. Evaluation and treatment of pharyngitis in primary care practice: the difference between guidelines is largely academic. *Archives of Internal Medicine* 2006;166:1374–9.
31 Keeffe B, Subramanian U, Tierney WM *et al.* Provider response to computer-based care suggestions for chronic heart failure. *Medical Care* 2005;43:461–5.
32 Hunt DL, Haynes RB, Hanna SE and Smith K. Effects of computer-based clinical decision support systems on physician performance and patient outcomes: a systematic review. *Journal of the American Medical Association* 1998;280:1339–46.
33 Tierney WM, Overhage JM, Murray MD *et al.* Effects of computerized guidelines for managing heart disease in primary care. *Journal of General Internal Medicine* 2003; 18:967–76.
34 Subramanian U, Fihn SD, Weinberger M *et al.* A controlled trial of including symptom data in computer-based care suggestions for managing patients with chronic heart failure. *American Journal of Medicine* 2004;116:375–84.
35 Murray MD, Harris LE, Overhage JM *et al.* Failure of computerized treatment suggestions to improve health outcomes of outpatients with uncomplicated hypertension: results of a randomized controlled trial. *Pharmacotherapy* 2004;24:324–37.
36 Tierney WM, Overhage JM, Murray MD *et al.* Can computer-generated evidence-based care suggestions enhance evidence-based management of asthma and chronic obstructive pulmonary disease? A randomized, controlled trial. *Health Services Research* 2005;40:477–97.
37 Eccles M, McColl E, Steen N *et al.* Effect of computerised evidence based guidelines on management of asthma and angina in adults in primary care: cluster randomised controlled trial. *British Medical Journal* 2002;325:941.
38 Rousseau N, McColl E, Newton J, Grimshaw J and Eccles M. Practice based, longitudinal, qualitative interview study of computerised evidence based guidelines in primary care. *British Medical Journal* 2003;326:314.
39 Montgomery AA, Fahey T, Peters TJ, MacIntosh C and Sharp DJ. Evaluation of computer based clinical decision support system and risk chart for management of hypertension in primary care: randomised controlled trial. *British Medical Journal* 2000;320:686–90.
40 Demakis JG, Beauchamp C, Cull WL *et al.* Improving residents' compliance with standards of ambulatory care: results from the VA Cooperative Study on Computerized Reminders. *Journal of the American Medical Association* 2000;284:1411–16.
41 Sequist TD, Gandhi TK, Karson AS *et al.* A randomized trial of electronic clinical reminders to improve quality of care for diabetes and coronary artery disease. *Journal of the American Medical Informatics Association* 2005; 12:431–7.
42 Samore MH, Bateman K, Alder SC *et al.* Clinical decision support and appropriateness of antimicrobial prescribing: a randomized trial. *Journal of the American Medical Association* 2005;294:2305–14.
43 Gross PA and Bates DW. A pragmatic approach to implementing best practices for clinical decision support systems in computerized provider order entry systems. *Journal of the American Medical Informatics Association* 2007;14:25–8.
44 Metlay JP, Camargo CA, MacKenzie T *et al.* Cluster-randomized trial to improve antibiotic use for adults with acute respiratory infections treated in emergency departments. *Annals of Emergency Medicine* 2007;50: 221–30.
45 Ranji SR, Steinman MA, Shojania KG *et al. Antibiotic Prescribing Behavior.* Rockville, MD: Agency for Healthcare Research and Quality, 2006.
46 Madle G, Kostkova P, Mani-Saada J, Weinberg J and Williams P. Changing public attitudes to antibiotic prescribing: can the internet help? *Informatics in Primary Care* 2004;12:19–26.

CONFLICTS OF INTEREST

Dr Linder has received research grants from Roche to examine antibiotic and antiviral medication prescribing for influenza and Pfizer Inc. to study electronic adverse drug event reporting.

ADDRESS FOR CORRESPONDENCE

Jeffrey A Linder MD MPH FACP
Division of General Medicine and Primary Care
Brigham and Women's Hospital
1620 Tremont Street, BC-3–2X
Boston MA 02120
USA
Email: jlinder@partners.org

Accepted December 2009