Impact of clinical decision support on receipt of antibiotic prescriptions for acute bronchitis and upper respiratory tract infection

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ABSTRACT

Objective Antibiotics are commonly recognized as non-indicated for acute bronchitis and upper respiratory tract infection (URI), yet their widespread use persists. Clinical decision support in the form of electronic warnings is hypothesized to prevent non-indicated prescriptions. The purpose of this study was to identify the effect of clinical decision support on a common type of non-indicated prescription.

Materials and methods Using National Ambulatory Medical Care Survey data from 2006 to 2010, ambulatory visits with a primary diagnosis of acute bronchitis or URI and orders for antibiotic prescriptions were identified. Visits were classified on the basis of clinician report of decision-support use. Generalized estimating equations were used to assess the effect of decision support on likelihood of antibiotic prescription receipt, controlling for patient, provider, and practice characteristics.

Results Clinician use of decision support increased sharply between 2006 (16% of visits) and 2010 (55%). Antibiotic prescribing for acute bronchitis and URI increased from ∼35% of visits in 2006 to ∼45% by 2010. Use of decision support was associated with a 19% lower likelihood of receiving an antibiotic prescription, controlling for patient, provider, and practice characteristics.

Discussion In spite of the increased use of decision-support systems and the relatively fewer non-indicated antibiotic prescriptions resulting from the use of decision support, a secular upward trend in non-indicated antibiotic prescribing offset these improvements.

Conclusions The overall effect of decision support suggests an important role for technology in reducing non-indicated prescriptions. Decision support alone may not be sufficient to eliminate non-indicated prescriptions given secular trends.

BACKGROUND AND SIGNIFICANCE

The Health Information Technology for Economic and Clinical Health (HITECH) Act was passed in 2009 to spur adoption and ‘meaningful use’ of health information technology (health IT). As part of meaningful use requirements, eligible healthcare providers are required to electronically monitor for drug–drug and drug–allergy interactions and make use of clinical decision-support systems, which include electronic warning systems or alerts to highlight potential contraindications for prescriptions ordered.

Meaningful use of decision support may reduce medication errors and inappropriate and unnecessary prescriptions. This effect has been demonstrated in some cases, such as the substitution of generic for branded medication.[1] Other studies have shown mixed impacts of decision-support use on non-indicated prescriptions for elderly patients and the impact of adding an electronic warning for medications with black-box warnings to an existing electronic medical record (EMR).[2 3] However, an overall and nationally representative assessment of the impact of decision support on non-indicated prescriptions has not been conducted.

To better understand the overall impact of decision support, it is necessary to narrow the focus to a specific set of encounters and resulting prescriptions over the broadest possible population. In particular, prescriptions that provide little to no benefit to individual patients or to the population are especially concerning, as overuse not only provides no added value, but their systematic overuse may also actually detract value. One such example is non-indicated antibiotic prescriptions.

Antibiotics generally provide little to no benefit for most cases of acute bronchitis and upper respiratory tract infection (URI) [4–6] and are of particular concern because of rising levels of antibiotic-resistant microorganisms.[7] Despite their ineffectiveness, such prescriptions remain common.[8 9] Up to 50% of all antibiotic prescriptions are for non-clinically indicated viral respiratory infections.[10 11]

The American Academy of Pediatrics and the American College of Physicians have both issued guidelines for reducing antibiotic use for acute bronchitis and URI,[4 12] and, beginning in 2008, the Healthcare Effectiveness Data and Information Set (HEDIS) has tracked antibiotic prescriptions for acute bronchitis through their NQF-endorsed ‘Avoidance of antibiotic treatment in adults with acute bronchitis’ measure.[13] Additional distinctions have been made between broad- and narrow-spectrum antibiotics, with broad-spectrum antibiotics being of particular concern, as they may disproportionately contribute to antibiotic resistance.[14]

In spite of these widespread efforts to reduce use, antibiotic prescriptions for acute bronchitis and other respiratory tract infections persist.[8 9 15] To date, the overall impact of decision support on the diversion of non-indicated prescriptions such as antibiotics for acute bronchitis or URI has not been assessed in a large, national sample.

OBJECTIVE

This study seeks to strengthen the existing literature on the impact of health IT in ambulatory care

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through examination of the impact of decision support on antibiotic prescriptions for outpatient cases of acute bronchitis and URI. We use diffusion-of-innovation theory to guide our examination of the observed effects of decision support using separate cross-sectional samples for each year from 2006 to 2010. As this study uses 5 years of data, we also examine trends in the adoption of health IT by office-based ambulatory providers from 2006 through 2010 and clarify the extent to which the relationship of decision support and antibiotic prescribing changes over time.

MATERIALS AND METHODS

Logic model

Nyquist *et al*[10] suggest four possible causes of outpatient antibiotic overprescribing: education, experience, expectations, and economics. We hypothesize that decision support acts to improve condition-specific education and enhance a clinician's previous experiences.[16] Improvements in these areas through decision support should yield fewer antibiotic prescriptions for acute bronchitis or URI, leading to improved clinical performance and patient safety.

Several potential confounders are addressed through the study's logic model. Provider's use of other forms of health IT was assessed through provider's use of e-prescribing and provider's use of EMR, both of which may influence likelihood of decision-support use and antibiotic-prescribing practices.[17–20]

Several other factors can affect provider responses to decision-support alerts. Provider practice setting factors such as office type (ie, private practice, health maintenance organization (HMO), other) and physician specialty are related to likelihood of decision-support and health IT usage and to antibiotic-prescribing practices.[8 21–24]

Patient factors such as type of insurance used and patient race/ethnicity may also affect prescribing patterns through expectations and economic incentives and are associated with differential decision-support use.[10 23 25–29] Additional factors such as patient age and the presence of pulmonary-related chronic conditions such as asthma or chronic obstructive pulmonary disease (COPD) were included as both are likely to affect a clinician's decision-making with respect to antibiotic prescriptions.[8 10]

Finally, relying on diffusion-of-innovation theory, we posit that the earliest adopters may be the most quality conscious, and that, if so, the impact of decision support on reducing non-indicated antibiotic prescriptions will be stronger for early adopters of decision support, and the positive benefit will diminish over time as later adopters use the innovation.[30] We examine overall adoption trends by estimating the relationship between decision support and antibiotic prescriptions by year and consider whether the provider was an early adopter of the technology or among the later adopters.

Data and sample

Data from the 2006, 2007, 2008, 2009, and 2010 National Ambulatory Medical Care Survey (NAMCS) were used for this study. NAMCS is a nationally representative survey of non-federally employed, office-based providers of ambulatory medical care services.[31] Data are collected from a nationally representative, stratified sample of clinicians on an annual basis. Each clinician provides data on his or her practice characteristics and a random sample of patient visits during a 1-week period. Sampling and data collection methods are described in detail elsewhere.[32] The NAMCS sample is refreshed annually and there is no method to link responding clinicians or patients across years. Data for each year were combined to create the analytic sample, with indicator variables for each study year.

We used International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9) diagnosis codes to identify visits with a primary diagnosis of bronchitis or URI (acute bronchitis, ICD-9 code 466; bronchitis not otherwise specified, ICD-9 code 490; acute URI of multiple or unspecified sites, ICD-9 code 465; acute nasopharyngitis, ICD-9 code 460). These definitions are consistent with previous studies.[8 10 25 33] A total of 3808 cases met these inclusion criteria.

Cases in which the patient's secondary diagnoses would indicate an antibiotic prescription were excluded. Exclusionary secondary diagnoses, ICD-9 codes, and the number of cases excluded by each are shown in detail in the online supplementary appendix. Exclusion criteria are consistent with previously published studies.[8 25 33] A total of 491 cases were excluded, for a final sample size of 3317 cases.

Antibiotic prescriptions were identified using the National Committee for Quality Assurance HEDIS 'Avoidance of antibiotic treatment for adults with acute bronchitis' list.[13] See online supplementary appendix for a complete list of antibiotics used in this study. Codes for each of these prescriptions were then matched to the NAMCS dataset using the NAMCS drug entry list and generic codes data. A board-certified internal medicine physician reviewed this coding strategy for accuracy and completeness.

Provider's use of decision support was assessed in the NAMCS provider survey with the question: 'Are there warnings of drug interactions or contraindications provided?' Response categories were 'Yes', 'No', 'Unknown', and 'Turned off'. Respondents were considered to have the technology if they answered 'Yes'; those who responded 'Unknown' or 'Turned off' were considered not to have decision support.

Multivariable models controlled for several factors outlined above in the logic model. Provider's use of e-prescribing and provider's use of EMR were assessed at the clinician level by NAMCS and were added as dichotomous variables. A categorical description of the clinician's office type was included with three categories: private practice, HMO, and other. Clinician specialty was also included as a three-category variable: general practitioner, pediatrics, and all others. Patient factor variables included insurance type (private, Medicare, Medicaid, self-pay, and other), age (0–4, 5–17, 18–64, 65+), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other), and dichotomous variables for the presence of two pulmonary-related chronic conditions: asthma and COPD.

Analyses

To track trends in antibiotic prescribing over time, univariate statistics were compiled for each year. Survey weights were used in all to account for the complex NAMCS sampling design. Multivariable generalized estimating equations (GEE) with an exchangeable correlation structure were used to estimate the overall effect of decision support on receipt of antibiotics, controlling for the potential confounders discussed in the logic model above. The GEE models correct for clustering in prescribing patterns at the physician level and yield population-averaged estimates. GEE models used the binomial family and a logit link function.[34]

The main model used data from all 5 years (2006–2010). Post-estimation tests were performed to calculate marginal probabilities and risk ratios. Risk ratios were bootstrapped with 1000 repetitions using the percentile method.[35]

We estimated additional models to assess the sensitivity of the results to alternative model specifications. First, we ran models for each data-year separately in order to assess changes in the relation of decision-support and antibiotic-prescribing behavior over time. Second, in order to more closely examine the effect of decision support for early adopters versus later adopters, we ran a GEE model that contained an interaction term between use of decision support and the overall proportion of providers using decision support in the year in which the visit occurred. Early adopters may be more sympathetic to the goals of decision-support systems, and accordingly the effects of decision support may have been greater in earlier years than in later years as the technology became more widely adopted. Third, to estimate the effect of decision support on receipt of broad- versus narrow-spectrum antibiotics, we limited the sample to acute bronchitis/URI visits for which an antibiotic prescription was ordered (40% of visits) and ran a GEE model to assess whether use of decision support was associated with a change in likelihood of antibiotic prescription receipt. All coding and data analysis was performed using Stata V.13.1.

RESULTS

The analytic sample is summarized in table 1. Of particular note are the large and statistically significant increases in the proportion of providers using decision support (16–55%, $p<0.001$), e-prescribing (13–56%, $p<0.001$), and EMR (14–47%, $p<0.001$) between 2006 and 2010. No other variables differed significantly across years at the $p=0.05$ level.

Figure 1 shows antibiotic prescription orders for outpatient visits with a primary diagnosis of acute bronchitis or URI. For the overall sample, 39.8% of acute bronchitis/URI visits resulted in antibiotic prescriptions, with some two-thirds of these antibiotic prescriptions for broad-spectrum antibiotics. There is no evidence that antibiotic prescribing for acute bronchitis/URI declined between 2006 and 2010. If anything, it would appear that there was an upward trajectory in overall prescribing across years, as the end points (2006 and 2010) were borderline significantly different ($p=0.10$). There were no significant changes in broad- versus narrow-spectrum composition or between year differences in either broad- or narrow-spectrum prescribing.

In adjusted analyses, use of decision support is associated with significantly reduced odds of antibiotic prescription receipt (OR 0.72, $p=0.03$). A full set of model estimates is shown in table 2. After adjustment for other covariates in the model and for the intra-provider correlation, the odds of a provider ordering an antibiotic prescription for acute bronchitis or URI visits are 0.72 times as great for providers who have decision support systems as for providers who do not have such systems ($p<0.05$).

Table 1 Characteristics of ambulatory care visits for acute bronchitis/URI, by year

Variable	2006 (%)	2007 (%)	2008 (%)	2009 (%)	2010 (%)	All years (%)
Patient received antibiotic prescription	34.1	40.3	40.6	38.8	45.4	39.8
Provider uses decision support*	16.1	17.6	34.6	39.9	54.5	31.8
Provider uses e-prescribing*	13.2	16.2	30.4	35.9	55.6	29.4
Provider uses EMR*	14.5	18.7	25.1	36.2	47.3	27.9
Patient insurance type						
Private	56.0	54.2	61.2	52.9	55.8	55.8
Medicare	7.6	13.6	13.6	14.1	12.8	12.4
Medicaid	25.5	21.0	17.9	27.2	23.6	23.2
Self-pay	2.6	4.7	3.4	3.1	2.4	3.3
Other	2.0	1.9	0.9	1.1	3.0	1.7
Provider office type						
Private practice	85.4	87.9	89.4	90.1	86.3	87.9
HMO	2.0	1.8	1.3	1.2	2.8	1.8
Other	12.6	10.3	9.3	8.3	10.9	10.3
Provider specialty						
Pediatrics	35.3	38.2	36.1	32.8	36.3	35.7
General/family medicine	42.4	36.6	41.5	47.4	37.1	41.1
Other	22.3	25.2	22.5	19.8	26.7	23.2
Patient age (years)						
0–4	29.3	29.2	30.5	22.9	30.5	28.3
5–17	19.0	20.6	16.5	22.3	18.7	19.5
18–64	42.1	35.4	37.8	39.9	37.6	38.6
>65	9.6	14.8	15.3	14.9	13.2	13.6
Patient race						
Non-Hispanic white	62.6	63.4	67.4	69.0	66.1	65.6
Non-Hispanic black	12.2	10.7	9.8	10.6	12.2	11.1
Hispanic	17.1	14.6	13.7	15.6	15.5	15.3
Other	8.0	11.4	9.1	4.9	6.3	8.0
Patient chronic condition(s)						
None	3.8	3.2	4.2	6.5	4.1	4.4
Asthma	7.8	8.9	9.4	8.4	10.9	9.0
COPD	28.7	24.7	23.3	26.9	19.9	24.9
Unweighted cases (n)	580	690	631	722	694	3317

*$p<0.001$.
COPD, chronic obstructive pulmonary disease; EMR, electronic medical record; HMO, health maintenance organization; URI, upper respiratory infection.

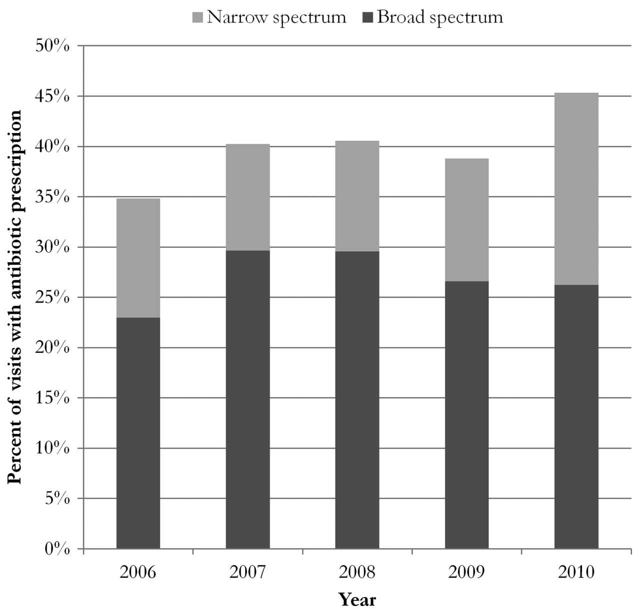

Figure 1 Percentage of acute bronchitis or URI visits resulting in antibiotic prescription.

Relative risk calculations for the sample (table 3) suggest that the overall relative risk of receiving an antibiotic prescription was associated with a decrease of some 19% when decision support was used. Stratifying the sample across each separate year shows little evidence of a differential effect across years. The year-specific estimates are similar in magnitude to the all-years estimate, but do not achieve statistical significance, reflecting lower sample size for the year-specific estimates.

The results of a separate GEE model that included an interaction term for the use of decision support and the overall proportion of providers using decision support in a given year were highly consistent with the overall analyses (see online supplementary appendix for full model results). In these analyses, the OR and SE for the decision-support coefficient was consistent with that observed in the main model (relative risk 0.69; bootstrapped 95% CI 0.49 to 0.90), while the coefficient for the interaction term was not statistically significant (relative risk for lowest vs highest value 1.32; bootstrapped 95% CI 0.93 to 1.85).

In GEE models assessing differences in the impact of narrow- versus broad-spectrum antibiotics, we found that clinician's use of decision support was only borderline significantly associated with an increased likelihood of broad- versus narrow-spectrum antibiotic receipt (p=0.11). Contrary to our hypothesis, however, the use of decision support was, if anything, positively associated with receipt of broad-spectrum antibiotic (relative risk 1.38; bootstrapped 95% CI 0.97 to 2.11).

The trends in non-indicated antibiotic use (figure 2) indicate that, at any given point in time, decision support helps reduce the likelihood of antibiotic prescription for acute bronchitis or URI. There is an upward secular trend, however, for both decision-support and non-decision-support users. On net, as the composition of decision-support users changes, antibiotic rates remain the same, even though decision support reduces non-indicated prescriptions and is expanding.

Table 2 ORs from GEE regression on receipt of antibiotic prescription

Variable	OR
Provider uses decision support	0.72*
Provider uses e-prescribing	1.36
Provider uses EMR	1.02
Provider specialty	
Pediatrics	*Reference*
General/family medicine	2.07***
Other	1.95***
Provider office type	
Private practice	*Reference*
HMO	0.23**
Other	0.90
Patient insurance type	
Private	*Reference*
Medicare	0.92
Medicaid	0.80*
Self-pay	1.25
Other	0.77
Patient age	
0–4	0.62**
5–17	0.85
18–64	*Reference*
> 65	0.79
Patient race	
Non-Hispanic white	*Reference*
Non-Hispanic black	1.25
Hispanic	0.81
Other	0.54**
Patient chronic condition(s)	
Asthma	0.86
COPD	2.78***
NAMCS year	
2006	*Reference*
2007	1.36*
2008	1.55**
2009	1.20
2010	1.82***
Constant	0.31***

*p<0.05;
**p<0.01;
***p<0.001.
COPD, chronic obstructive pulmonary disease; EMR, electronic medical record; GEE, generalized estimating equation; HMO, health maintenance organization; NAMCS, National Ambulatory Medical Care Survey.

DISCUSSION

Our study—the first large-scale, nationally representative examination of the association of clinical decision support with orders for antibiotic prescriptions in cases of acute bronchitis or URI—found that, despite ongoing efforts aimed at reducing or eliminating prescriptions for such diagnoses, a substantial proportion—nearly 40%—of outpatient visits for acute bronchitis or URI result in a prescription for antibiotics. Despite public-awareness campaigns and guidelines, use of broad-spectrum antibiotics appeared to be at least as prevalent, if not more, than previously estimated,[14] with no apparent downward trend. It is especially notable that no change in prescribing was observed before and after the 2008 introduction of a HEDIS measure in this area.

Consistent with the existing literature, NAMCS data from 2006 to 2010 reveal a sharp increase in clinician use of three forms of health IT: decision support, e-prescribing, and EMR. Each rose from approximately 10–15% prevalence in 2006 to

Table 3 Relative risk of receipt of antibiotic prescription with use of decision support, by year

Year	Relative risk of receiving antibiotic prescription with use of decision support(95% CI*)
All years	0.81 (0.66 to 0.96)
2006	0.83 (0.35 to 1.53)
2007	0.98 (0.68 to 1.46)
2008	0.93 (0.63 to 1.37)
2009	0.85 (0.59 to 1.22)
2010	0.81 (0.59 to 1.14)

*CIs bootstrapped using 1000 repetitions, percentile method shown.

over 50% by 2010. We believe this diffusion and the resulting diverse range of users is a strength of this study, as it enabled us to measure the effect of decision support on the early adopters using it in 2006 and the early/late majority using it in 2010.[30]

With respect to the impact of decision support on antibiotic prescriptions for acute bronchitis and URI, our results suggest that, after relevant patient and provider factors are accounted for, the use of decision-support systems is associated with a significantly lower likelihood of receiving an antibiotic prescription. Specifically, the likelihood of receiving an antibiotic prescription is 0.81 times as great for acute bronchitis or URI visits where the provider reports having decision support capabilities as for visits where the provider reports not having them. Even though decision support systems were becoming increasingly common from 2006 to 2010, an upward secular trend in antibiotic prescribing appears to have wiped out gains that may otherwise have accrued with wider use of decision support. More research will be required to understand the reasons for this upward secular trend.

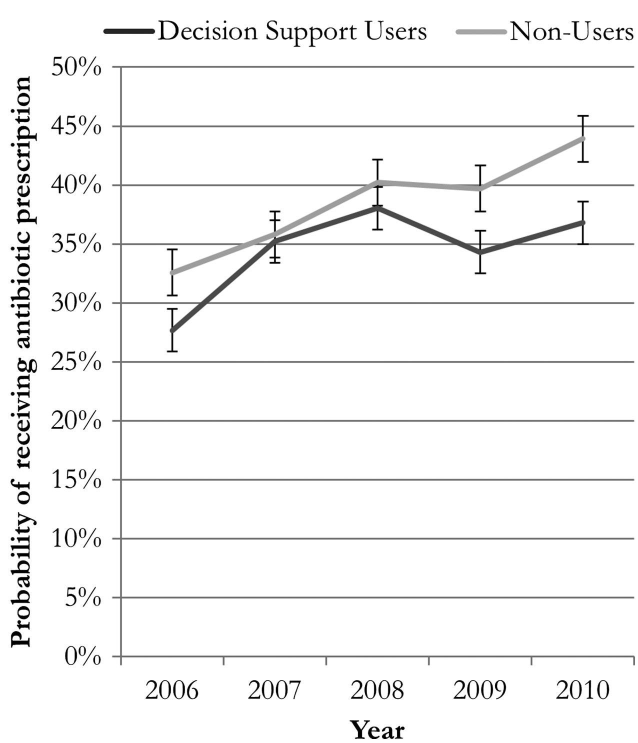

Figure 2 Adjusted probability of receiving antibiotic prescription, decision support users versus non decision support users.

To provide some context for the estimate of the effect of decision support on antibiotic prescribing, the data used in this study represent an average of approximately 830 million ambulatory encounters per year between 2006 and 2010. Nearly 27 million of these visits are for acute bronchitis or URI. With ~40% of all such visits resulting in an order for an antibiotic prescription, more than 10 million such prescriptions occur annually. A 20% decline in acute bronchitis or URI antibiotic prescribing could translate to over one million fewer antibiotic prescriptions per year (assuming approximately half of clinicians use decision support, as in 2010) or potentially as many as two million fewer prescriptions annually if all clinicians were to use decision support.

Our estimate of the impact of decision support on prescribing is consistent with previous studies examining the impact of a specific clinical decision support system or technological intervention on prescribing behavior for acute bronchitis/URI[36 37] and for other evidence-based prescription diversion efforts.[38] The modest effect size of decision support we found is roughly comparable to other studies of individual clinical decision-support systems[33] or of decision support plus community interventions[39] on antibiotic-prescribing patterns. We hypothesized that decision support would influence two of the four potential reasons for antibiotic prescribing for acute bronchitis (education and experience, but not expectations or economics).[10] An electronic warning may be insufficient to avert a prescription in the face of strong economic incentives or patient expectations for a prescription, although it may be enough to tip the scales in the absence of these factors. So a reduction of some 20% is not unreasonable.

Other forms of health IT, including EMRs and e-prescribing, did not have any significant impact on the likelihood of receiving an antibiotic prescription for acute bronchitis. All of the categorical patient- and clinician-level covariates included in our model were significant. We interpreted these results as evidence that the net effectiveness of decision support, as with many other forms of health IT, is associated with a range of patient- and clinician-level sociotechnical factors.[40]

This study expands on earlier research by providing an estimate of the overall impact of decision-support systems nationwide for patients with bronchitis. This estimate suggests that decision support is associated with a roughly 20% decline in the likelihood of antibiotic prescription, which could represent hundreds of thousands of averted prescriptions that are wasteful and in some cases harmful.

Decision support could make an especially important contribution given that acute bronchitis and URI visits account for ~10 million antibiotic prescriptions per year. Recent analysis of all 260–270 million antibiotic prescriptions per year shows declines of ~3% in overall prescribing from 2006 to 2010.[41] Without further data, however, we cannot be certain whether the decline is due to changing opportunities to prescribe or changing tendencies to prescribe given the opportunity. For example, it could be that improvements in care have led to a reduction in conditions that require antibiotics. Our data suggest that, when the opportunity to prescribe is separated out from the tendency to prescribe given the opportunity, the tendency to prescribe is going up for outpatient acute bronchitis and URI visits.

To add context to our estimates, we also ran a model that included an interaction term between use of decision support and the overall proportion of providers using decision support in the year in which the visit took place. If we believe that the observed decision-support effect is not due to the warnings themselves but to some underlying construct, say attentiveness to quality, which is associated with both the likelihood of decision-support usage and the likelihood of antibiotic prescribing, then we would expect that the observed effect of decision support would wane as it became more widely used. We were able to observe this in our data as decision support became much more common between 2006 (16% of visits) and 2010 (55% of visits); we are thus able to observe in this dataset the early adopters using it in 2006 (ie, those most attentive to quality) and the later majority using it in 2010 (ie, those slightly less attuned to quality). In this scenario we would expect the observed relationship to attenuate over time. This model demonstrates that no such attenuation occurred for acute bronchitis visits between 2006 and 2010, as the effect of decision support was significant and similar in magnitude with and without the year-specific-usage interaction term.

Together these results suggest that there is no greater effect of decision-support systems among early adopters than among later adopters. This should strengthen confidence in the conclusion that the decision support itself is responsible for the observed effects and not an unmeasured covariate or a merely spurious correlation.

With respect to the types of antibiotic prescriptions ordered, we found no effect of decision support on broad- versus narrow-spectrum antibiotics. While we might have expected a decision-support capability to be especially beneficial in averting broad-spectrum prescriptions, as these are hypothesized to be especially problematic at the system level, there was no effect due to decision support. It is possible that the specific warnings or information currently being generated by clinicians' systems do not adequately differentiate between broad- and narrow-spectrum agents.

Our study has relevant limitations to note. First, our measure of decision-support usage was limited by data available through NAMCS. IT system use is measured at the provider level rather than at the visit level. IT functionalities may or may not be used for a given visit,[42–44] and our data do not contain information on the specific conditions or warnings generated by each clinician's system. Thus, we cannot be sure that all of the reported decision-support users were subject to the effect of decision support for antibiotic prescriptions. We are also not able to assess the nature and salience of the decision support provided by each clinician's system. Since we do not measure the specificity, visibility, or intrusiveness of alerts, we are mixing alerts that may be more or less effective at averting antibiotic prescriptions. This would result in an underestimate of the impact of a highly effective alert system. These measurement issues all tend to dilute the observed effect of decision support and may result in an understatement of the true impact of decision support. Second, we were not able to measure the sociotechnical and cultural factors that are often hypothesized to moderate the system effectiveness of health IT on patient safety.[16 45] These contextual factors are notably absent from all large-scale datasets, so this limitation is not unique to our study.[16] Third, although we utilized multiple years of cross-sectional data and carefully accounted for other relevant factors in our conceptual model, we are not able to demonstrate causality. Decision-support users and non-users may differ in other unmeasured respects. To address this, we have presented statistical and conceptual rationale in the discussion above for why spuriousness is not likely to be the cause of our findings. We also note that use of decision support has diffused rapidly throughout our study period. Whatever between-group differences existed in 2006 would have been at least partially diluted by later adopters who used decision support by 2010.[30] Fourth, our study may have been limited by somewhat small samples for each year of data, limiting the sub-sample analyses possible. By pooling several years of data we were able to overcome this potential limitation, although we were thus unable to identify any trends over time in the impact of decision support on antibiotic-prescribing practices for acute bronchitis or URI.

CONCLUSION

Our results indicate that decision support can play a role in reducing antibiotic prescribing for acute bronchitis and URI. On the whole, there is a roughly 20% decrease in the likelihood of antibiotic prescribing for clinical decision-support users. An effect of this size might be expected to avert one million non-indicated antibiotic prescriptions annually, a major achievement and one that could help clinicians improve the care they deliver and their performance on at least one HEDIS measure. The end result of this is a reduction in inappropriate antibiotic use and a concomitant reduction in the spread of antibiotic-resistant bacteria.

In addition to the effect of decision support itself, several patient- and clinician-level variables also helped explain antibiotic-prescribing practices in the study's nationwide ambulatory care sample. These findings reiterate the complex and interdependent nature of prescriptions and emphasize the role that technology can play in achieving desired outcomes in conjunction with efforts aimed at other system stakeholders.

The magnitude of the reduction in likelihood of antibiotic prescribing for acute bronchitis or URI due to use of decision support underscores that this tool can play an important role in reducing non-indicated antibiotic prescriptions, but its use alone is unlikely to substantially reduce non-indicated antibiotic prescriptions or to substantively affect the likelihood of broad- versus narrow-spectrum prescribing. Quality improvement initiatives might therefore look to decision support as a tool to facilitate appropriate prescribing, but additional clinician and patient education efforts are likely warranted.

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Collaborators Douglas S Bell; Paul R Torrens.

Contributors JMM conceived and designed the study. JMM was responsible for acquisition of data. All authors were responsible for data analysis and interpretation. JMM drafted the manuscript, and FJZ and HPR revised it critically for important intellectual content. HPR supervised the study. All authors have given final approval of the version to be published and agree to be accountable for all aspects of the work.

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