Ambulatory prescribing errors among community-based providers in two states

Erika L Abramson,[1,2,3] David W Bates,[4,5,6] Chelsea Jenter,[4] Lynn A Volk,[6] Yolanda Barrón,[2] Jill Quaresimo,[7] Andrew C Seger,[4] Elisabeth Burdick,[4] Steven Simon,[4,5,8] Rainu Kaushal[1,2,3,9]

[1]Department of Pediatrics, Weill Medical College of Cornell University, New York, New York, USA
[2]Department of Public Health, Weill Medical College of Cornell University, New York, New York, USA
[3]New York Presbyterian Hospital, New York, USA
[4]Division of General Internal Medicine, Brigham and Women's Hospital, Boston, Massachusetts, USA
[5]Harvard Medical School, Boston, Massachusetts, USA
[6]Information Systems, Partners Healthcare System, Boston, Massachusetts, USA
[7]Taconic IPA, Fishkill, New York, New York, USA
[8]VA Boston Healthcare System, Boston, Massachusetts, USA
[9]Department of Medicine, Weill Medical College of Cornell University, New York, New York, USA

Correspondence to
Dr Erika Abramson, Departments of Pediatrics and Public Health, Weill Medical College of Cornell University, 525 East 68th Street, Room-M-610, New York, NY 10065, USA; err9009@med.cornell.edu

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ABSTRACT

Objective Little is known about the frequency and types of prescribing errors in the ambulatory setting among community-based, primary care providers. Therefore, the rates and types of prescribing errors were assessed among community-based, primary care providers in two states.

Material and Methods A non-randomized cross-sectional study was conducted of 48 providers in New York and 30 providers in Massachusetts, all of whom used paper prescriptions, from September 2005 to November 2006. Using standardized methodology, prescriptions and medical records were reviewed to identify errors.

Results 9385 prescriptions were analyzed from 5955 patients. The overall prescribing error rate, excluding illegibility errors, was 36.7 per 100 prescriptions (95% CI 30.7 to 44.0) and did not vary significantly between providers from each state (p=0.39). One or more non-illegibility errors were found in 28% of prescriptions. Rates of illegibility errors were very high (175.0 per 100 prescriptions, 95% CI 169.1 to 181.3). Inappropriate abbreviation and direction errors also occurred frequently (13.4 and 4.2 errors per 100 prescriptions, respectively). Reviewers determined that the vast majority of errors could have been eliminated through the use of e-prescribing with clinical decision support.

Discussion Prescribing errors appear to occur at very high rates among community-based primary care providers, especially when compared with studies of academic-affiliated providers that have found nearly threefold lower error rates. Illegibility errors are particularly problematical.

Conclusions Further characterizing prescribing errors of community-based providers may inform strategies to improve ambulatory medication safety, especially e-prescribing.

Trial registration number http://www.clinicaltrials.gov, NCT00225576.

Medication errors occur frequently, may be harmful, and result in considerable costs. A study of adult inpatients found 5.3 prescribing errors per 100 paper orders, with 6.6% having potential for harm and 0.9% resulting in actual harm.[1] One estimate of national costs for preventable adverse drug events (ADE) affecting inpatients was US$2 billion annually.[2]

In contrast to the inpatient setting, much less is known about prescribing errors in the outpatient setting. A study of four adult academic-affiliated primary care practices in Boston, Massachusetts, found errors in one in 13 prescriptions (7.6%), with nearly half having potential for harm. The error rate among the providers using hand-written prescriptions was 11%.[3] Other studies have found even higher prescribing error rates among paper-based prescribers, although few studies have focused on community-based providers who do the majority of ambulatory prescription writing.[4–7]

Detecting prescribing errors in the outpatient setting is challenging because patients frequently have multiple providers and pharmacies, and copies of prescriptions are generally unavailable for review. Despite these challenges, understanding the frequency and types of outpatient prescribing errors is critical because an estimated 2.6 billion medications are provided, prescribed, or continued at ambulatory visits annually.[8] Furthermore, rates of preventable ADE in the ambulatory setting are high and many patients experience sequelae requiring medical care.[9–12]

Improving healthcare safety is a goal of major national policy forces such as the American Reinvestment and Recovery Act, which aims to increase the adoption of health information technology, including e-prescribing, by offering billions of dollars of incentives to providers who demonstrate meaningful use of electronic health records (EHR).[13] Core measures of the meaningful use criteria include computer entry of medication orders, implementation of specific clinical decision support (CDS) to assist in medication ordering, and electronic transmission of prescriptions to pharmacies. Therefore, better understanding the rates and types of prescribing errors made by providers may inform the design and CDS strategies for e-prescribing systems, which are expected to be increasingly adopted by providers so that they can be eligible for incentives.

We therefore conducted this study to determine the rates and types of prescribing errors among paper-based, primary care prescribers in solo and small group practices in two communities, and to determine the potential impact of e-prescribing on these errors.

METHODS

Study design

We conducted this cross-sectional study of 78 ambulatory care providers in the Hudson Valley Region of New York and Brockton, Massachusetts, from September 2005 to November 2006. We analyzed carbon copies of all prescriptions written by participating providers during a 2-week period for the presence of prescribing errors, ensuring that we obtained at least 75 prescriptions on 25 patients per provider and extending data collection if necessary to achieve these numbers. We limited prescription review to three randomly selected prescriptions per patient to minimize clustering of errors. Non-duplicate prescription pads were removed during study periods to maximize compliance with duplicate prescription pad use. The study received approval from the Kingston Institutional Review Board in the Hudson Valley and the Caritas Good Samaritan Medical Center Institutional Review Board in Brockton.

Definitions

We focused on errors that occurred during the prescription writing process and classified errors in accordance with definitions from the Institute of Medicine.[2] Classification included rule violations, prescribing errors with low potential to cause harm, (referred to as 'prescribing errors'), near misses, and ADE. The least harmful type of error was rule violations, which were departures from strict standards of prescribing that were unlikely to result in harm. An example was failure to write 'po' for a medication only taken orally. Rule violations were not included in error counts. An example of a prescribing error with low potential to cause harm was prescribing an anti-hypertensive medication but omitting the quantity to be dispensed. Near misses were errors with high potential for harm that were either intercepted or reached the patient but did not result in harm. One example was prescribing penicillin to a patient with a known allergy who took the medication but did not have a reaction. Actual ADE were injuries from a medication, some of which were associated with an error and therefore considered preventable.

Sites

The Hudson Valley is a predominantly rural and suburban area north of New York City. Brockton is the sixth largest city in Massachusetts located 25 miles south of Boston. Most of the 78 providers worked in practices ranging in size from one to seven providers and none of the practices was affiliated with an academic medical center.

The New York providers were all members of the not-for-profit Taconic Independent Practice Association (Taconic IPA). A letter was sent to members in May 2005 detailing incentives for adopting e-prescribing systems and inviting providers to participate in a research study. Providers were given additional discounts on EHR licenses as an incentive for participation in the research study.

The Massachusetts providers were identified with the help of the Massachusetts eHealth Collaborative (MAeHC), which is a coalition formed in 2004 of the state's major healthcare stakeholders to pursue community-wide EHR implementation.[14] The principal investigator and study staff approached individual physicians in Brockton, one of the MAeHC target communities, for participation. No monetary incentives were offered to participate in the research study, although providers were given free EHR by the MAeHC to encourage adoption.

Data review

Prescription review

One physician (RK) trained a research nurse and research pharmacist in an identical manner using well-utilized, standardized methodology.[3 15–18] Training included review of error definitions, assessment of legibility, and review of test and actual cases. A prescription was deemed illegible if it could be easily misinterpreted or was indecipherable. Reviews were initially conducted in pairs, after which the research nurse reviewed the Hudson Valley prescriptions and the pharmacist reviewed the Brockton prescriptions. Rule violations, prescribing errors, near misses, and ADE were all classified.[15] We determined interrater reliability by having the pharmacist and nurse evaluate the same random sample of 2% of the data. The κ score for agreement between the research nurse and pharmacist was 0.81, indicating very good to excellent agreement. For all suspected near misses and ADE, the research nurse or pharmacist performed a review of the patient's outpatient medical record to determine any sequelae.

Physician event review and classification

We conducted physician reviews for all suspected near misses and ADE. Confirmed ADE were rated on preventability using a five-point Likert scale and on attribution (ie, the certainty with which the medication was the explanation for the observed adverse event) using the Naranjo algorithm, which uses factors such as known medication side-effect profiles, timing of patient-reported symptoms, and documented use of antidotes to assess attribution.[19] ADE were also classified on the level of severity as significant, serious, life-threatening, or fatal. For the New York providers, two physicians reviewed events independently. The κ score for interrater agreement for the presence of near misses was 0.95 ($p<0.001$), demonstrating excellent agreement. For the Massachusetts providers, a separate group of physicians conducted reviews jointly to reach consensus.

Finally, we examined each individual error to determine whether using e-prescribing with either basic or advanced CDS could have prevented the error. Consistent with other studies, we defined basic CDS as CDS that ensured completeness in prescribing fields and eliminated illegibility errors; all other CDS features, such as prescribing alerts, were defined as advanced.[3 7 20] We did not count errors preventable with basic CDS as also preventable with advanced CDS.

Statistical analysis

We calculated overall error rates per 100 prescriptions and compared error rates for providers in the two communities using mixed-effects Poisson regression, to adjust for clustering at the provider level. We assumed an independent correlation structure for all Poisson models. We calculated 95% Poisson CI with cluster-robust standard errors for the rates. We also compared the presence of any error per prescription using logistic mixed-effects models, adjusting for clustering with provider as the unit of analysis. The only available provider characteristics were age, sex and year since graduation and they were not included in the Poisson or logistic mixed models as covariates. We used SAS for PC V.9.1 to estimate κ statistics, χ^2, Fisher's exact, and t tests and Stata V.11, to estimate mixed-effects Poisson and logistic models, and to calculate 95% Poisson and logistic CI with clustered robust standard errors.

RESULTS

Prescriber characteristics

Forty-eight providers were from New York and 30 were from Massachusetts (table 1). There was no significant difference between the groups of providers in gender, degree, or years since graduation.

Patient characteristics

We reviewed a total of 5873 prescriptions from 3808 unique patients seen by the New York providers and 3512 prescriptions

Table 1 Characteristics of healthcare providers

	Office practice		
	NY N=48	MA N=30	p Value
Female	21 (44%)	12 (40%)	0.74
Years since graduation Mean (SD)	17 (8)	17 (10)	1.00
Degree			
MD or DO	35 (73%)	26 (87%)	0.22
Nurse practitioner	8 (17%)	4 (13%)	
Physician assistant	5 (10%)	0 (0%)	

DO, doctor of osteopathy; MA, Massachusetts; MD, doctor of medicine; NY, New York.

from 2147 unique patients seen by the Massachusetts providers (table 2). The patients seen by New York providers were significantly older than those seen by Massachusetts providers (mean age 54 vs 51 years, p<0.001). There was no significant difference in patient gender.

Error rates

Both groups of providers had high error rates (table 3). Rule violations occurred at a rate of 54.4 per 100 prescriptions. Prescribing errors, including illegibility errors, occurred at a rate of 212.6 per 100 prescriptions. Providers in Massachusetts had a higher error rate than providers in New York (p=0.01). However, when illegibility errors were excluded, the prescribing error rate was 36.7 per 100 prescriptions and there was no statistically significant difference in rates between provider groups (p=0.39). Excluding illegibility errors, 27.8% of prescriptions had at least one prescribing error.

We found an overall near miss rate of 1.5 per 100 prescriptions. We did not find a difference in rates between provider groups (p=0.55). Excluding illegibility errors from near miss counts, the near miss rate was 1.1 per 100 prescriptions. The overall rate of preventable ADE we detected was low (0.15 per 100 prescriptions).

Types of errors

The most common types of prescribing errors among providers at both sites were illegibility errors, use of inappropriate abbreviations, direction errors and strength errors (table 4). Among near misses, illegibility errors and dose errors occurred most frequently. The most common illegible fields were strength or strength unit, medication name and frequency. Examples of errors are provided in box 1.

Prescribing errors by drug category

Prescribing errors most frequently involved antibiotics (n=1516, 16.4%), followed by cholesterol medications (n=530, 5.7%), narcotic analgesics (n=500, 5.4%) and anti-hypertensive drugs (n=468, 5.1%).

Table 2 Patients with prescriptions

	NY N=3808	MA N=2147	p Value
Age: mean (SD)	54 (17)	51 (18)	<0.001
Female gender	2388 (63%)	1324 (62%)	0.43

MA, Massachusetts; NY, New York.

Potential impact of e-prescribing

In addition to preventing all illegibility errors, reviewers determined that e-prescribing with basic CDS may have prevented 1092 of the remaining 3443 prescribing errors (32%), and advanced CDS may have prevented another 1966 of the remaining prescribing errors (57%) (tables 5 and 6). Errors judged preventable by basic CDS, aside from illegibility errors, were omission errors. Most frequently, these were strength or dose errors, such as omitting strength or dose units. All other errors were judged preventable by advanced CDS. The most frequent types were inappropriate abbreviation errors and direction errors, such as directions for use incorrect or discrepant. For the near misses we detected, basic CDS would have prevented all 38 illegibility errors and may have prevented 44 of the remaining 104 near misses (42%), while advanced CDS may have prevented an additional 38 (36%). There was no significant difference between the two groups of providers in the rates of errors preventable with basic and advanced CDS.

DISCUSSION

We found that approximately one in four prescriptions written by community-based providers in two states had at least one error, even without counting illegibility errors. Illegibility errors occurred on average more than once per prescription. The use of an e-prescribing system has the potential to reduce error rates markedly. E-prescribing systems linked with advanced CDS may have an even bigger impact, especially on errors with higher potential for harm.

Our study is one of only a few to characterize prescribing errors in ambulatory care settings and we are not aware of other multistate studies that have been performed. In comparing the providers from New York and Massachusetts, there was no significant difference in prescribing error rates for non-illegibility errors. Our observed rate of errors seems generally similar to that of other studies, although methodologies vary between studies and rates may differ between academic and community settings.[3 5 6] For example, despite the use of the same methodology and pharmacist reviewer, the percentage of hand-written

Table 3 Rates of errors

	N			Rates per 100 prescriptions (95% CI)*			
	Total	NY	MA	Total	NY	MA	p Value†
	9385	5873	3512	–	–	–	
Rule violations	5103	3463	1640	54.4 (46.8 to 63.2)	59.0 (49.2 to 70.7)	46.7 (36.5 to 59.8)	0.13
Prescribing errors	19 956	11 043	8913	212.6 (186.2 to 243.0)	188.0 (155.7 to 227.3)	253.8 (215.1 to 299.5)	0.01
Prescribing errors excluding illegibility errors	3443	2007	1436	36.7 (30.7 to 44.0)	34.1 (29.6 to 39.5)	40.9 (28.0 to 58.8)	0.39
Near misses	142	94	48	1.5 (1.2 to 1.9)	1.6 (1.2 to 2.2)	1.4 (0.9 to 2.0)	0.77
Near misses excluding illegibility errors	104	65	39	1.1 (0.9 to 1.4)	1.1 (0.8 to 1.5)	1.1 (0.7 to 1.6)	0.80
ADE	14	1	13	0.15 (0.07 to 0.31)	0.02 (0.002 to 0.12)	0.37 (0.18 to 0.76)	0.004

*Clustered adjusted Poisson 95% CI.
†Poisson regression adjusting for clustering comparing rates for NY and MA.
ADE, adverse drug event; CDS, clinical decision support; MA, Massachusetts; NY, New York.

Table 4 Types of prescribing errors and near misses

	Number (%) Overall	Rate per 100 prescriptions (95% CI)*	
		Rate	95% CI
No of prescriptions	9385		
Prescribing errors† (N)	19 956	212.6	(186.2 to 243.0)
Type of error			
Illegibility errors	16 513 (82.8)	175.1	(148.6 to 206.3)
Inappropriate abbreviation	1230 (6.2)	13.1	(8.2 to 20.9)
Directions error	394 (2.0)	4.2	(3.4 to 5.1)
Strength error	392 (2.0)	4.2	(3.4 to 5.2)
Dose error	344 (1.7)	3.7	(2.5 to 5.3)
Length of treatment error	333 (1.7)	3.5	(2.4 to 5.2)
Frequency error	192 (1.0)	2.0	(1.6 to 2.7)
Amount error	172 (0.9)	1.8	(1.3 to 2.7)
Other errors‡	386 (1.7)	4.1	(3.2 to 5.4)
Near misses (N)	142	1.5	(1.2 to 1.9)
Type of error			
Illegibility errors	38 (26.8)	0.40	(0.31 to 0.63)
Frequency error	27 (19.0)	0.29	(0.18 to 0.42)
Directions error	22 (15.5)	0.23	(0.15 to 0.35)
Dose error	14 (9.0)	0.14	(0.08 to 0.25)
Strength error	11 (7.7)	0.12	(0.06 to 0.21)
Route error	3 (2.1)	0.03	(0.007 to 0.09)
Inappropriate abbreviation	2 (1.4)	0.02	(0.003 to 0.08)
Other errors§	25 (17.6)	0.26	(0.17 to 0.39)

*Cluster-adjusted Poisson CI.
†Excluding rule violations.
‡For example, refill errors.
§For example, drug–drug interaction errors.

prescriptions containing at least one error in a study of four academic-affiliated primary care clinics in Boston was 11% compared with our rate of 27.8%.[3] Community-based providers may have different prescribing patterns and fewer support systems than academic-affiliated providers, leading to higher error rates.

Box 1 Examples of prescribing errors and near misses

Prescribing errors*

Ketoconazole 2% antifungal cream is prescribed without directions for use.

Lortisone cream (betamethasone and clotrimazole cream) is ordered with length of treatment omitted.

Rhinocort Aqua nasal spray (budesonide nasal spray) is prescribed with frequency illegible.

Amoxicillin 500 mg is prescribed with length of treatment omitted.

Near misses

Imitrex 100 mg (sumatriptan) is ordered with frequency for use omitted.

Vicodin 7.5–750 mg (hydrocodone and acetaminophen) is ordered for '1 tablet every 4 h', which exceeds maximum daily dose of acetaminophen.

Lasix (furosemide) is ordered with strength omitted.

Ortho Evra contraceptive patch (ethinyl estradiol and norelgestromin transdermal system) instructions incorrectly written as 'apply one patch monthly'.

*Including illegibility errors, excluding rule violations.

Table 5 Errors judged to be preventable with basic CDS

Type of error	Preventable prescribing errors N (%)	Preventable near misses N (%)
Overall	17 605	82
Illegibility error	16 513 (93.8%)	38 (46.3%)
Strength error	330 (1.9%)	9 (11.0%)
Dose error	277 (1.6%)	7 (8.5%)
Frequency error	160 (0.9%)	19 (23.2%)
Amount to be dispensed error	132 (0.7%)	0
Directions error	112 (0.6%)	4 (4.9%)
Length of treatment error	81 (0.5%)	1 (1.2%)
Route error	0	2 (2.4%)
Date error	0	1 (1.2%)
Refill error	0	1 (1.2%)

CDS, clinical decision support.

Although the majority of errors we detected were unlikely to result in serious patient harm, some might. Furthermore, even the less serious errors are important to study for their potential impact on efficiency as well as patient safety. Illegible prescriptions or those with missing information can lead to pharmacy filling errors or callbacks for clarification. Substantial time may be wasted for patients, prescribers, and pharmacists given the high frequency with which prescribing errors appear to occur. Callbacks probably also have important clinical implications. For example, a study evaluating pharmacy callbacks to 22 primary care practices to clarify prescriptions found that callbacks were common and problems for 'acute' medications, defined as medications in which administration delays could lead to worsening of a medical condition or cause prolonged pain, were not resolved on the same day 34% of the time.[21]

In addition, although our methods were not designed to capture near misses or preventable ADE, we still detected a near miss rate of 1.5 per 100 prescriptions and there were likely to be additional near misses and preventable ADE that occurred but were not detected. A previous study showed that 4% of ambulatory patients with prescription errors experienced a preventable ADE.[3] Further studies should be conducted in the community setting with methods specifically suited to detecting near misses and preventable ADE.

Understanding the epidemiology of prescribing errors in the outpatient setting can inform strategies for reducing their frequency and severity. This includes the use of e-prescribing, which has significant potential for improving patient safety.[7 22] We found an overall rate of 175.1 illegibility errors per 100 prescriptions, all of which would be eliminated by even the most

Table 6 Errors judged to be preventable with advanced CDS

Type of error	Preventable prescribing errors N (%)	Preventable near misses N (%)
Overall	1966	38
Inappropriate use of abbreviation	1230 (62.6%)	2 (5.3%)
Directions error	277 (14.1%)	18 (47.4%)
Length of treatment error	252 (12.8%)	0
Dose error	64 (3.3%)	7 (18.4%)
Strength error	58 (3.0%)	2 (5.3%)
Amount to be dispensed error	38 (1.9%)	0
Frequency	29 (1.5%)	7 (18.4%)
Route error	0	1 (2.6%)
Other	18 (0.9%)	1 (2.6%)

CDS, clinical decision support.

basic e-prescribing system. However, advanced CDS appears important to achieve even greater safety gains.

By characterizing ambulatory prescribing errors, CDS can be designed so that it targets the most frequent types of errors. For example, the two most common types of errors we found that were judged to be preventable with advanced CDS were inappropriate abbreviation errors and direction errors. CDS that automatically converted inappropriate abbreviations into acceptable abbreviations would eliminate this type of error. Pre-populated direction fields with clear and complete instructions for certain drugs might eliminate many direction errors. Future studies should be conducted to determine the actual impact of various e-prescribing systems with CDS on ambulatory prescribing errors, as few such studies have been conducted.[3 4 22–25] This is particularly important given the expected increase in use of e-prescribing as a result of the federal stimulus package and meaningful use criteria.[13]

Our study has several limitations. We had only one reviewer for each prescription, although joint review of a subset of prescriptions revealed excellent agreement. This may account for differences in rates of prescribing errors between the New York and Massachusetts providers when illegibility errors were included, as ultimately the determination of legibility is subjective. We focused on prescribing errors and were limited by our methods to comment on near misses and ADE. In addition, the providers in our study were not blinded to the study's purpose. Our error rates might, therefore, be underestimates if physicians attempted to be particularly careful while writing prescriptions during the study period. The practices that elected to participate might not be representative of all practices, and might have lower rates than practices at large.

CONCLUSION

Few studies have characterized the rates and types of prescribing errors made by community-based providers in the ambulatory setting. Our findings suggest that these errors occur in one in four prescriptions, even without counting illegibility issues, which occur at a rate of more than one per prescription. Therefore, handwritten prescriptions are simply not safe. Many of these errors may be preventable through the use of e-prescribing systems, especially when linked with advanced CDS. By evaluating the rates and types of ambulatory prescribing errors made by community-based providers, findings from this study can inform current policies aimed at improving outpatient medication safety.

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Competing interests None.

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REFERENCES

1. **Bates DW,** Boyle DL, Vander Vliet MB, *et al*. Relationship between medication errors and adverse drug events. *J Gen Intern Med* 1995;**10**:199–205.
2. **Kohn LT,** Corrigan J, Donaldson MS. *Institute of Medicine (U.S.). Committee on Quality of Health Care in America. To Err is Human: Building a Safer Health System*. Washington, DC: National Academy Press, 2000.
3. **Gandhi TK,** Weingart SN, Seger AC, *et al*. Outpatient prescribing errors and the impact of computerized prescribing. *J Gen Intern Med* 2005;**20**:837–41.
4. **Devine EB,** Hansen RN, Wilson-Norton JL, *et al*. The impact of computerized provider order entry on medication errors in a multispecialty group practice. *J Am Med Inform Assoc* 2010;**17**:78–84.
5. **Shaughnessy AF,** Nickel RO. Prescription-writing patterns and errors in a family medicine residency program. *J Fam Pract* 1989;**29**:290–5.
6. **Devine EB,** Wilson-Norton JL, Lawless NM, *et al*. Characterization of prescribing errors in an internal medicine clinic. *Am J Health Syst Pharm* 2007;**64**:1062–70.
7. **Kaushal R,** Kern LM, Barrón Y, *et al*. Electronic prescribing improves medication safety in community-based office practices. *J Gen Intern Med* 2010;**25**:530–6.
8. **Cherry DK,** Hing E, Woodwell DA, *et al*. National Ambulatory Medical Care Survey: 2006 summary. *Natl Health Stat Report* 2008:1–39. http://www.cdc.gov/nchs/data/nhsr003.pdf (accessed 31 Aug 2011).
9. **Institute of Medicine.** *Preventing Medication Errors*. Washington, DC: The National Academies Press, 2006.
10. **Thomsen LA,** Winterstein AG, Søndergaard B, *et al*. Systematic review of the incidence and characteristics of preventable adverse drug events in ambulatory care. *Ann Pharmacother* 2007;**41**:1411–26.
11. **Gandhi TK,** Weingart SN, Borus J, *et al*. Adverse drug events in ambulatory care. *N Engl J Med* 2003;**348**:1556–64.
12. **Gurwitz JH,** Field TS, Harrold LR, *et al*. Incidence and preventability of adverse drug events among older persons in the ambulatory setting. *JAMA* 2003;**289**:1107–16.
13. *U.S. Department of Health and Human Services [American Recovery and Reinvestment Act of 2009]*. http://www.hhs.gov/recovery/ (accessed 11 Nov 2011).
14. **Goroll AH,** Simon SR, Tripathi M, *et al*. Community-wide implementation of health information technology: the Massachusetts eHealth Collaborative experience. *J Am Med Inform Assoc* 2009;**16**:132–9.
15. **Bates DW,** Kaushal R, Keohane CA, *et al*. Center of excellence for patient safety research and practice terminology training manual. 2005:1–21. http://www.patientsafetyresearch.org/ (accessed 31 Aug 2011).
16. **Kaushal R,** Goldmann DA, Keohane CA, *et al*. Adverse drug events in pediatric outpatients. *Ambul Pediatr* 2007;**7**:383–9.
17. **Kaushal R.** Using chart review to screen for medication errors and adverse drug events. *Am J Health Syst Pharm* 2002;**59**:2323–5.
18. **Kaushal R,** Bates DW, Landrigan C, *et al*. Medication errors and adverse drug events in pediatric inpatients. *JAMA* 2001;**285**:2114–20.
19. **Naranjo CA,** Busto U, Sellers EM, *et al*. A method for estimating the probability of adverse drug reactions. *Clin Pharmacol Ther* 1981;**30**:239–45.
20. **Abramson E,** Barron Y, Quaresimo J, *et al*. Electronic prescribing within an electronic health record reduces ambulatory prescribing errors. *Jt Comm J Qual Patient Saf* 2011;**37**:470–8.
21. **Hansen LB,** Fernald D, Araya-Guerra R, *et al*. Pharmacy clarification of prescriptions ordered in primary care: a report from the Applied Strategies for Improving Patient Safety (ASIPS) collaborative. *J Am Board Fam Med* 2006;**19**:24–30.
22. **Ammenwerth E,** Schnell-Inderst P, Machan C, *et al*. The effect of electronic prescribing on medication errors and adverse drug events: a systematic review. *J Am Med Inform Assoc* 2008;**15**:585–600.
23. **Eslami S,** Abu-Hanna A, de Keizer NF. Evaluation of outpatient computerized physician medication order entry systems: a systematic review. *J Am Med Inform Assoc* 2007;**14**:400–6.
24. **Feldstein AC,** Smith DH, Perrin N, *et al*. Reducing warfarin medication interactions: an interrupted time series evaluation. *Arch Intern Med* 2006;**166**:1009–15.
25. **Smith DH,** Perrin N, Feldstein A, *et al*. The impact of prescribing safety alerts for elderly persons in an electronic medical record: an interrupted time series evaluation. *Arch Intern Med* 2006;**166**:1098–104.