Research and Applications

Computerized prescriber order entry–related patient safety reports: analysis of 2522 medication errors

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ABSTRACT

Objective: To examine medication errors potentially related to computerized prescriber order entry (CPOE) and refine a previously published taxonomy to classify them.

Materials and Methods: We reviewed all patient safety medication reports that occurred in the medication ordering phase from 6 sites participating in a United States Food and Drug Administration–sponsored project examining CPOE safety. Two pharmacists independently reviewed each report to confirm whether the error occurred in the ordering/prescribing phase and was related to CPOE. For those related to CPOE, we assessed whether CPOE facilitated (actively contributed to) the error or failed to prevent the error (did not directly cause it, but optimal systems could have potentially prevented it). A previously developed taxonomy was iteratively refined to classify the reports.

Results: Of 2522 medication error reports, 1308 (51.9%) were related to CPOE. Of these, CPOE facilitated the error in 171 (13.1%) and potentially could have prevented the error in 1137 (86.9%). The most frequent categories of "what happened to the patient" were delays in medication reaching the patient, potentially receiving duplicate drugs, or receiving a higher dose than indicated. The most frequent categories for "what happened in CPOE" included orders not routed to or received at the intended location, wrong dose ordered, and duplicate orders. Variations were seen in the format, categorization, and quality of reports, resulting in error causation being assignable in only 403 instances (31%).

Discussion and Conclusion: Errors related to CPOE commonly involved transmission errors, erroneous dosing, and duplicate orders. More standardized safety reporting using a common taxonomy could help health care systems and vendors learn and implement prevention strategies.

Key words: medication safety, computerized provider order entry, health information technology, electronic prescribing, medication errors

BACKGROUND AND SIGNIFICANCE

Rapid adoption and use of electronic health records (EHRs) in the United States has occurred in recent years in part as a result of financial incentives from the Center for Medicare and Medicaid Services to meet meaningful use criteria.[1] Ongoing efforts to maximize the benefits of using EHRs and reduce unintended consequences are needed in order to promote the quality and safety of this investment and ensure optimal patient care and outcomes.[2] Computerized prescriber order entry (CPOE) and accompanying clinical decision support systems are important components of EHRs that have been shown to reduce medication error rates overall. However, CPOE can also facilitate new types of errors.[3–12] A recent analysis of health information technology (HIT)–related adverse events reported to 2 patient safety organizations (PSOs) noted that errors involving CPOE were among the most common types of HIT errors resulting in adverse events.[13] The National Academy of Medicine (formerly the Institute of Medicine), the Office of the National Coordinator for HIT, and the National Quality Forum have called for expanded efforts to identify, analyze, and address the causes of these errors, so that prevention strategies can be developed and implemented in order to achieve the full safety benefits of CPOE.[1,2,14] In response to this call, our research team has engaged in a series of studies to better understand the vulnerabilities of CPOE for medication ordering.[15–18] We had previously reviewed and classified 10 000 errors related to CPOE from the US pharmacopeia MEDMARX database and developed a taxonomy classification system for the types of errors and their causes, and suggested prevention strategies.[15] More recently, our team of pharmacists, physicians, and health IT specialists reviewed multiple types of medication error data from several CPOE systems for a multicenter US Food and Drug Administration (FDA)–funded project, Computerized Prescriber Order Entry Medication Safety (CPOEMS), with overall findings summarized in a white paper and commentary.[16,17] As one component of the CPOEMS study, we collected all available medication safety reports from participating institutions. These reports have not previously been systematically analyzed either within the 6 institutions or across the collaborating sites that agreed to share their anonymized data with the CPOEMS research team.

Therefore, the aim of the current study was to analyze these safety reports to identify and classify those related to CPOE. In addition, we aimed to further develop and refine a taxonomy classification system for CPOE-related errors.

MATERIALS AND METHODS

The CPOEMS study was a 2-year study that evaluated different CPOE systems in order to learn about the potential role of CPOE in medication errors and identify opportunities for improvement.[16,17] As a convenience sample, 10 CPOE systems at 6 sites were evaluated. These included both inpatient and outpatient systems, and in-house–developed as well as commercial systems, at academic medical centers, a large managed care organization, and a multispecialty community group practice. In the first phase of the study, the CPOEMS team assessed the CPOE systems' features and identified problematic issues with medication ordering display and workflow. The second phase of the study involved a review of several different sources of information, including safety and adverse event or error reports, at each of the sites. We collected and reviewed all available error reports from the 6 sites that occurred from January to December 2013 ($n = 2522$) to identify reports of medication errors that occurred in the ordering phase of the medication use process and analyze which errors could be classified as CPOE-related. The reports were supplied by individual study site investigators as those that were obtained as part of the institution's voluntary error reporting systems. When the institution classified the reports into the ordering phase (vs other phases of the medication use process), we examined only those reports. Two clinical pharmacists (M.G.A., A.S.) independently reviewed each error report narrative to (1) confirm that the error occurred in the ordering/prescribing phase, and (2) determine whether it was related to the use of CPOE. For those errors that were related to the use of CPOE, taxonomy codes were then assigned for "what happened/what went wrong," and if causal factors could be determined from the report, "why" the error occurred. Patient medical records were not reviewed, and assignment of error categories was based solely on information included in the error reports.

Taxonomy revision

Our original CPOE error taxonomy contained 101 codes for "what went wrong," 67 codes describing reasons "why" errors occurred, and 73 codes describing potential prevention strategies.[15] To further refine this taxonomy, we used the medication error reports from the CPOEMS sites to further refine the classification system. Our aim was to better consolidate overlapping codes and clarify concepts that were ambiguous or insufficiently precise. Additionally, we created a new conceptualization by categorizing our original (and more ambiguous) "what went wrong" classification into "what happened to the patient" (eg, patient received a dose higher than indicated) vs "what went wrong during CPOE ordering of the medication" (eg, incorrect units were entered or wrong dosage form was ordered). The final version of the taxonomy included categories for "what happened to the patient" (16 codes), "what happened in CPOE" (64 codes), and "why" the error occurred (73 codes) (see Appendix). In assigning codes, we grouped together errors that may have reached patients and those that were intercepted, to avoid having separate codes for each that would result in a code redundancy and a much larger number of codes for the reviewer to work with. Thus terminology such as "the patient received or nearly received" was used as inclusive whether or not the error was detected before it reached the patient.

Additional coding considerations

In addition to coding "what happened to the patient," "what happened in CPOE," and "why" it happened, we also assessed whether CPOE facilitated (ie, actively contributed to) the error or failed to prevent the error (ie, did not directly cause, but with more optimal design, such as better implemented clinical decision support, could potentially have prevented the error). A coding manual with rules for coding specific types of cases was developed during the coding process and is included in the white paper describing the overall CPOEMS project findings.[17] Cases with uncertainties in code selection were discussed and resolved between the 2 coders, and remaining questions were discussed with the study team. A random sample of 50 error reports were coded by both pharmacists, with excellent agreement on whether the error was facilitated by CPOE or was not prevented by CPOE (κ 0.83) and both "what happened" categories (κ 0.87), and moderate agreement on "why" the error happened (κ 0.58).

RESULTS

A total of 2522 medication error reports from 6 sites were identified as having errors in the medication ordering phase. Of these, we

Table 1. Patient safety and error reports reviewed and role of CPOE by site, 2013

Role of CPOE in Error	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Total (%Reports)
CPOE related	202	37	13	107	37	912	1308 (51.9)
CPOE facilitated the error	42	3	3	11	19	93	171 (13.1)
CPOE failed to prevent the error	160	34	10	96	18	819	1137 (86.9)
Unrelated to CPOE	32	3	265	396	22	496	1214 (48.1)
Total	234	40	278	503	59	1408	2522

classified 1308 (51.9%) as CPOE-related. CPOE was thought to directly facilitate or cause the error in 171 (13.1%), and to fail to prevent the error in 1137 (86.9%) (Table 1).

The types of errors that were coded as facilitated by CPOE included: erroneous names in the system for drug formulations; problems entering the order leading to a workaround (eg, forcing providers to enter conflicting information in the comments field); confusing or difficult to read screen display; misleading prepopulated fields; routing an order to a destination not intended by the prescriber; pulldown menu/adjacency problems; outdated order sets, protocols, and drug dictionaries; and features of CPOE that facilitated wrong-patient errors (eg, ability to have multiple patient profiles open at the same time). The types of errors that we coded as those CPOE failed to prevent included: inadequate computerized decision support alerts (eg, lacking alerts for duplicate orders, high doses, clinically significant drug interactions, or timing of medications), lack of electronic communication of discontinuation of CPOE-originated orders to the pharmacy, medication reconciliation errors, and lack of features to prevent drug name confusion (eg, metoprolol succinate vs tartrate; clomiphene/clomipramine).

Examples of representative cases and how they would be coded with the taxonomy are included in BOX 1.

Tables 2 and 3 list taxonomy codes used to classify "what happed to the patient" and "what happened in CPOE." The most frequently coded categories for what happened to the patient were delays in medication reaching the patient (33.9%), patient receiving or potentially receiving a duplicate (same drug or in same therapeutic class) (16.2%), and patient receiving or nearly receiving a dose higher than indicated (10.6%), followed by risk of not receiving the medication (6.7%) or receiving the wrong drug (5.4%). The most frequent categories for "what happened when entering the order in CPOE" were orders not routed to or received at the intended destination (33.6%), ordering wrong dose or strength (12.1%), duplicate orders (10.7%), ordering a drug that was inappropriate or contraindicated (4.0%), and ordering the wrong dosage form or formulation (3.4%). The top 5 categories accounted for 72.8% and 63.8% of all categories assigned for what happened to the patient and what happened in CPOE, respectively. Ordering a wrong drug for drugs with look-alike, sound-alike names occurred relatively infrequently, in 1.1% of the cases reviewed.

Codes for "why" the error occurred could be assigned in only 403 (30.8%) of cases. The reason(s) why the error occurred could not be determined in the remaining 905 (69.2%), largely because the coding pharmacist did not find sufficient details in the narrative report to determine the cause of the error.

The 5 most common categories for "why" were:

1. **Order entry issues: system limitations/inadequacy: pharmacy routing issue** (Examples: A medication order was entered in the general care orders area, which is not transmitted to the pharmacy; an order for IV chemotherapy was entered in the wrong IV system, so did not cross over to the pharmacy system; an order was input in the emergency room, which did not cross over to the inpatient pharmacy system.)
2. **User issues: failure to follow established procedures or protocol** (Example: A vaccine was given in clinic and should have been recorded as given from clinic stock supply, but was entered as a prescription that was sent to the outpatient pharmacy and then filled by the pharmacist.)
3. **Order entry issues: system limitations/inadequacy: discontinuation orders not communicated or wrongly interfaced with pharmacy or EMR** (Example: A new blood pressure medication was started and an older medication discontinued in CPOE; however, the community pharmacy was not notified of the discontinued medication and the patient filled both the old and new prescriptions.)
4. **Transition issues: failure to perform adequate medication reconciliation** (Example: A necessary home medication was not entered in CPOE on admission.)
5. **Order entry issues: system limitations/inadequacy: absence of adequate CDS in CPOE system** (Example: A patient with renal insufficiency was prescribed a full dose of a medication with significant renal clearance when the dose should have been reduced; an alert might have guided appropriate dosing.)

Variations were seen in the format, categorization, and quality of reports among the study sites, often making it difficult to apply the classification taxonomy. All reports contained some type of narrative description of the error, although some reports included much more detail about outcomes, whether harm occurred, and potential contributing factors to the error, while others only included a brief description of the error. Most reports were completed by front-line staff (nurses, pharmacists, and providers); only some had follow-up investigation details added by patient safety personnel. Differences in types of reports and percent of reports that were pre-identified as occurring in the ordering phase made it difficult to make comparisons about types of errors among the different sites. This was due to some sites having preclassified errors occurring in the ordering phase (site 1), and thus more errors identified by reviewers as related to CPOE. Other site reports included more cases that our reviewers determined were not related to CPOE. These differences resulted in a wide variation in percentage of errors reviewed from each site that we classified as related to CPOE.

DISCUSSION

We collected and analyzed medication error safety reports where the error occurred in the ordering phase from 6 institutions to identify errors related to CPOE systems. Although classification systems for HIT safety problems and overall medication errors have been reported in the literature,[13,19,20] few studies have specifically examined or classified types of errors associated with CPOE. We used a

Box 1. Examples using coding taxonomy

Example 1: *Outpatient picking up refill received hydralazine instead of the intended hydroxyzine; prescriber had selected the wrong agent from a pulldown menu.*
"What happened to the patient": Drug: Patient received or nearly received wrong drug "What happened in CPOE": Drug: Ordered wrong drug; LASA (look alike, sound alike)
drug "Why": Order entry issues: System interface/usability/visual display issues; adjacency (including pulldown menu) issues
Example 2: *Prescriber enters orders for GI bleed using the GI bleed order set, which lists a proton pump inhibitor that is now nonformulary instead of the agent that is on the formulary. Prescriber is called and instructed to change the order.*
"What happened to the patient": Time: Delay in medication being given or dispensed "What happened in CPOE": Other: Problems with template or order set "Why": System limitations/inadequacy; drug not available or incorrect in order set
Example 3: *Prescriber intended to order enoxaparin 40 mg 2 times daily, but prescription was entered and approved as once daily. On review of error, it was noted that the provider did not notice that once daily was the default schedule.*
"What happened to the patient": Dose: Patient received or nearly received wrong dose; dose lower than indicated or appropriate "What happened in CPOE": Time: Wrong time, schedule, or frequency entered "Why": Order entry issues: System limitations/inadequacy; default settings facilitated error
Example 4: *Pharmacist called to question 2 antibiotics prescribed for a patient. One prescription was discontinued in the CPOE system but no call was made to the pharmacy to discontinue.*
"What happened to the patient": Drug: Patient received or nearly received a duplicate (same exact drug, or in same therapeutic class) "What happened in CPOE": Other: Entered order not routed to/received at intended destination "Why": System limitations/inadequacy: Discontinuation orders not communicated or wrongly interfaced with pharmacy or electronic medical record
Example 5: *Prescription was meant to be sent to one pharmacy, but was sent to another pharmacy because the preferred pharmacy was not changed when ordering.*
"What happened to the patient": Time: Delay in medication being given or dispensed "What happened in CPOE": Other: Entered order not routed to/received at intended
destination "Why": Unknown

Table 2. "What happened to the patient?" categories of CPOE-related errors

What happened to the patient?	Total (%)
Time: Delay in medication being given or dispensed	444 (33.9)
Drug: Patient received or nearly received a duplicate (same exact drug, or in same therapeutic class)	212 (16.2)
Dose: Patient received or nearly received wrong dose; dose higher than indicated or appropriate	138 (10.6)
Drug: Patient did not or nearly did not receive medication	87 (6.7)
Drug: Patient received or nearly received wrong drug	70 (5.4)
Dose: Patient received or nearly received wrong dose; dose lower than indicated or appropriate	66 (5.0)
Drug: Patient received or nearly received drug that was inappropriate or contraindicated	58 (4.4)
Dose: Patient missed or nearly missed dose	49 (3.7)
Drug: Patient received or nearly received wrong dosage form or formulation of correct drug	48 (3.7)
Patient: Wrong patient received or nearly received drug	41 (3.1)
Drug: Patient received or nearly received drug to which s/he was allergic	28 (2.1)
Dose: Patient received or nearly received wrong dose	28 (2.1)
Dose: Patient received or nearly received extra dose	19 (1.5)
Route: Patient received or nearly received drug early	11 (0.8)
Route: Patient received or nearly received medication via wrong route	8 (0.6)
Route: Patient received or nearly received medication on wrong side of the body (R vs L mixed up)	1 (0.1)
Total	1308

taxonomy our team originally developed based on a review of over 10 000 errors from the MEDMARX system, which we have refined during this review of over 2000 more recent reports analyzed in this study, where we noted many additional scenarios and types of errors. Comparing the most common types of errors from this review

to those from our prior MEDMARX error review revealed some similar leading categories, including erroneous dose, wrong formulation, and duplicate orders. However, other common errors found in the MEDMARX study, including missing or incomplete directions and missing quantity, were rarely seen in the current study. This may be due to improvements made to CPOE systems since the earlier study, such as blank field checking and structured prescription directions, that were not universally present when the previous MEDMARX errors were generated and reported (2003–2010); alternatively, the current error reporters may have judged "missing information" to be a less critical reason to file a safety report.

Reviewing this large number of errors has allowed for refinement and initial validation of our previous taxonomy to a more consolidated, less ambiguous version, although further testing is needed to evaluate its usefulness. Unfortunately, our ability to classify why errors occurred in most situations was suboptimal, signifying a need for better reporting formats and inclusion of more details by those reporting errors. Including an assessment of why an error happened in the report by safety personnel or others designated to analyze safety reports at a site would likely be more accurate and less ambiguous than one determined by secondary reviewers, as in this study.

Potential prevention strategies

A white paper and a commentary based on the findings of all data sources reviewed in the CPOEMS study include several recommendations for improving CPOE systems to avoid common problems and improve safety.[16,17] Those and some additional recommendations that apply to the most common types of errors identified in this analysis include the following:

- Orders not routed to or received at intended destination: Improved communication of prescriptions among prescribers, EHRs, and pharmacies should be addressed by designing systems to ensure that the destination of the prescription is understood

Table 3. Top 15 "What happened in CPOE?" categories of CPOE-related errors

What happened in CPOE?	CPOE Facilitated (n = 171)	CPOE Failed to Prevent (n = 1137)	Total (%) (n = 1308)
Other: Entered order not routed to/received at intended destination	35	405	440 (33.6)
Dose: Ordered wrong dose or strength	8	149	157 (12.1)
Drug: Duplicate order, same exact drug	15	125	140 (10.7)
Drug: Ordered drug that was inappropriate or contraindicated (by lab, disease, age, pregnancy, interactions with other drug, or patient's explicit refusal of drug)	3	49	52 (4.0)
Drug: Ordered wrong dosage form (IR, ER, SR, XR; tablets, capsules; oral, topical) or formulation	2	43	45 (3.4)
Drug: Ordered wrong drug	2	42	44 (3.4)
Drug: Failed to order drug; failed to renew or reorder drug (including home, chronic, held medications, antibiotic renewals)	0	38	38 (2.9)
Time: Wrong time, schedule, or frequency entered	8	22	30 (2.3)
Drug: Ordered drug to which patient was allergic	0	29	29 (2.2)
Drug: Failed to order drug	0	27	27 (2.1)
Dose: Medication number or quantity problem; wrong number or quantity indicated on order	0	22	22 (1.7)
Drug: Failed to order drug; failed to order an indicated drug or corollary order	1	18	19 (1.5)
Drug: Ordered wrong drug; ordered LASA	1	14	15 (1.1)
Time: Wrong time, schedule, or frequency entered; wrong order date	2	13	15 (1.1)
Dose: Failed to order dose change	0	13	13 (1.0)
Total (top 15 codes)			1086 (83.0)

decision support systems. Decision support alerts for duplicate therapy, renal and geriatric dosage adjustments, allergies, drug-drug interactions, drug-disease contraindications, and nonformulary medications should be consistently incorporated and tailored at each site. Overrides of these alerts should be tracked and evaluated in order to address inappropriate overrides and identify ineffective or unnecessary alerts. Better yet, alerts should be presented at the time of ordering instead of after orders or prescriptions have been entered, to increase acceptance rate, and hard stops can be used to prevent the most serious errors. In addition to decision support alerts, default dosing and/or access to drug information about usual doses should be incorporated into systems when necessary.

Improving error reports

Reports of adverse drug events and medication errors are more useful if they include well-written narrative reports in addition to structured data, and efforts to facilitate the creation of high-quality reports are needed.[21] A well-written report should be easy to submit yet include enough detail to determine factors that contributed to the error. A 2-stage process, particularly for more serious errors, where an initial brief report by front-line staff is followed by more detailed investigations of contributing factors and outcomes by safety personnel or other designated reviewers, could improve the quality of final reports. Using a standardized coding taxonomy system similar to ours could facilitate such investigations. Follow-up by personnel charged with investigating these events soon after they occur could also help to ensure that errors are fully analyzed and appropriately understood. Incorporating the error reporting system directly into the CPOE system and/or providing a link from the EHR to the error reporting system, with the ability to include screen captures of erroneous orders or import patient information, would simplify the error reporting process and provide more detail on factors contributing to errors. It would also enable timely feedback to CPOE vendors to allow for system improvements, or potentially send information to a PSO or HIT safety center to be used as a clearinghouse for CPOE-related medication errors.

PSOs currently are required to utilize the Agency for Healthcare Research and Quality's Common Formats to uniformly report patient safety events. The current version (1.2) of the Common Formats includes a separate classification for HIT among the types of patient safety event; types of HIT include EHRs, with a subcategory for CPOE. Further detailing the Common Format taxonomy to include more granular specifics about CPOE-related errors similar to our taxonomy could improve the ability to learn more about these types of errors. Ideally, institutions and vendors would use this information and share learning and recommendations for CPOE safety improvements with other institutions so that all may benefit and appropriate prevention strategies can be implemented.

LIMITATIONS

Given that the error reports we reviewed were voluntary reports, they likely do not represent all CPOE-related errors, as significant underreporting is common with voluntary reporting systems.[22–25] For example, problems with medications going to the wrong pharmacy and lack of communication of discontinuation of drugs are so frequent in current systems, it would probably not be practical to report them all. Both of these issues need to be addressed through system improvements. The subset of errors in our study represents only those errors that were both identified and reported, resulting in a

and easily entered or changed if necessary. Improving interoperability between order entry and pharmacy systems and between different locations of care is also important. Enhancements to prevent additional errors include incorporating the prescriber's ability to determine if a prescription has been received and filled, allowing electronic discontinuations to be received by outpatient pharmacies to prevent unintended filling of discontinued prescriptions, and including indication for use on electronic prescriptions to prevent errors and assist pharmacists in patient education.

- Ordering wrong dose or strength, making duplicate orders, or ordering drugs that are contraindicated in specific patients: Many of these types of errors should be reduced by more effective clinical

biased sample. The lack of detail in many of the reports limited our ability to fully understand the nature of the errors. These reports also often lacked information on the clinical outcomes of the medication errors, precluding our definitively assigning outcome severity (ie, the National Coordinating Council for Medication Error Reporting and Prevention stage).[26] The rates of some types of errors that occurred may have been impacted by the varying numbers of reports from different sites. One of the outpatient sites had a large number of prescriptions routed to an unintended (in-house) pharmacy, resulting in that type of error being the most frequent in their reports. Merely classifying errors using our taxonomy would not likely capture the full complexities and contexts involved in errors. Clearly, only a broader sociotechnical approach to HIT and understanding errors will be needed to more fundamentally address the complex prescribing/IT environment that is the context for these errors. In this paper and the companion pieces from the CPOEMS project, we have tried to push the envelope in this direction, but acknowledge that this represents tiny progress toward what we ultimately need. In this paper we focus on the "taxonomy classification," a key aim of this study. Although mindless review efforts confined to ticking off taxonomy boxes (what one reviewer dubbed "instrumental classification") are hardly the best way to learn from these incidents, such a structured review represents one tool for guiding a review of the reports and seeing patterns across aggregated reports. Finally, although multiple types of CPOE systems were studied for this project, these results may not be reproducible at sites with different CPOE or error reporting systems.

CONCLUSIONS

The most common errors related to ordering in CPOE in medication error reports in this study were transmission errors, erroneous dosing, and duplicate orders. Our review of error report narratives was useful in refining a taxonomy classifying CPOE-related errors by consolidating and clarifying error categories. A more standardized safety reporting process using a common taxonomy across health care facilities could enable health care systems and vendors to learn more about the causes of these types of errors and implement strategies to prevent them. Such adverse event information should be made more accessible within and across systems in order to systematically learn from past errors and issues and provide feedback to institutions and commercial vendors to assist in improving CPOE design and usability.

ETHICS APPROVAL

This study was reviewed and approved by the Partners Human Research Committee, which is the Institutional Review Board of Partners Research Management at Partners HealthCare (protocol #2012-P-002221; Brigham and Women's Hospital).

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CONTRIBUTION

GDS, AW, LAV, and DWB contributed to the conception and design of the study. TTH, AJLQ, WG, RK, BL, JA, JDM, and DHS conducted data collection and preparation, and MGA and AS reviewed and classified error reports. MGA, AS, TTH, AJLQ, DM, LAV, AW, DWB, and GDS contributed to analysis and interpretation of data and results. MGA, AS, LAV, and GDS led drafting and writing the manuscript and revising it critically, with all co-authors commenting on drafts. All authors gave their approval for the final version to be published.

COMPETING INTERESTS

No competing interests were identified by the authors of this manuscript.

SUPPLEMENTARY MATERIAL

Supplementary material are available at *Journal of the American Medical Informatics Association* online.

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