Development and Field Testing of a Self-Assessment Guide for Computer-Based Provider Order Entry

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EXECUTIVE SUMMARY

Despite the benefits of computerized provider order entry (CPOE), numerous reports of unexpected CPOE-related safety concerns have surfaced. As part of a larger project to improve the safety of electronic health records (EHRs), we developed and field tested a CPOE "safety self-assessment" guide through literature searches, expert opinion, and site visits. We then conducted a field test of this guide with nine hospital chief medical informatics officers (CMIOs), who were identified through the Association of Medical Directors of Information Systems. The CPOE safety self-assessment guide was sent electronically to the CMIOs. Once the assessments were returned, we conducted structured telephone interviews for further comments about the guide's format and content. The CMIOs in our study found the CPOE safety guide useful and relatively easy to complete, taking no more than 30 minutes. Analysis of responses to the guide suggest that most recommended practices were implemented inconsistently across facilities. Despite consensus for certain CPOE best practices in the medical literature and among experts, there appeared to be considerable variation among CMIOs' opinions of best practices. Interview data suggested this inconsistency was mostly due to system limitations and/or differing opinions about the necessity of certain EHR-related safety measures. Despite the absence of consensus on best practices, a self-assessment safety guide provides a practical starting point for organizations to assess and improve safety and the effectiveness of their CPOE system.

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BACKGROUND AND SIGNIFICANCE

The use of electronic health records (EHRs) and computerized provider order entry (CPOE) with advanced clinical decision support (CDS) has the potential to increase efficiency, reduce harm, and improve patient safety (Amarasingham, Plantinga, Diener-West, Gaskin, & Powe, 2009; Ammenwerth, Schnell-Inderst, Machan, & Siebert, 2008; Bates et al., 1999, 2001; Bobb et al., 2004; Franklin, O'Grady, Donyai, Jacklin, & Barber, 2007; Mekhjian et al., 2002; Sittig & Stead, 1994; Sittig & Singh, 2012; Wolfstadt et al., 2008). Despite these potential benefits, several barriers limit the adoption of these technologies, including high costs, major time commitments for training personnel, interruptions in workflow, and medical practitioners' reluctance to move away from traditional paper records (Kuperman & Gibson, 2003; Ash, Gorman, & Hersh, 1998; Wang & Huang, 2012).

To encourage widespread implementation of fully functional EHRs (i.e., EHRs that contain integrated CPOE and CDS applications), the U.S. Congress passed the Health Information Technology for Economic and Clinical Health (HITECH) Act as part of the 2009 American Recovery and Reinvestment Act (GPO, 2010). In 2010, HITECH allocated financial incentives totaling almost $27 billion to hospitals and eligible professionals (i.e., doctors of medicine or osteopathy, doctors of dental surgery or dental medicine, doctors of podiatric medicine, doctors of optometry, and chiropractors) who are able to demonstrate the "meaningful use" of EHRs, a critical component of which is CPOE with CDS (Wright, Feblowitz, Samal, McCoy, & Sittig, 2014). In view of the time limits on these incentives and the eventual financial penalties for nonadopters, since May 2012, 62,226 of the estimated 509,328 eligible physicians have attested to meaningful use of EHRs under the Medicare program (Vest, Yoon, & Bossak, 2013; Wright et al., 2013). Similarly, whereas only 27% of hospitals used CPOE in 2008, by 2012 the figure was 72% (Charles, King, Furukawa, & Patel, 2013).

CPOE has been described primarily as an innovation to improve patient safety, yet the implementation of CPOE within EHRs also has potential to introduce novel and unexpected risks. For example, Horsky, Kuperman, and Patel (2005) identified a series of errors in potassium chloride ordering resulting from a confluence of factors, including (1) misunderstandings about the patient's current potassium level due to ineffective display of recent laboratory results; (2) confusing displays of current orders and recent medication administrations; (3) misunderstandings surrounding the different meanings of "total volume" when ordering time-limited, continuous intravenous drips and amount-limited, intravenous bolus injections; and (4) use of free-text versus coded (i.e., computer-understandable) data entry. The effects of introducing fully functional EHRs into highly complex healthcare organizations are difficult to fully anticipate. It is not surprising that the accelerated pace of EHR implementation has given way to increasing

reports of unintended negative consequences resulting from the use of these technologies (Allen & Sequist, 2012; Ash, Sittig, Poon, et al., 2007; Ash, Sittig, Dykstra, et al., 2007; Ash, Sittig, Dykstra, Campbell, & Guappone, 2009; Berger & Kichak, 2004; Caldwell & Power, 2012; Campbell, Sittig, Ash, Guappone, & Dykstra, 2006; Campbell, Sittig, Guappone, Dykstra, & Ash, 2007; FitzHenry et al., 2007; Gandhi et al., 2005; Han et al., 2005; Horsky et al., 2005; Koppel et al., 2005, 2008; Koppel, Wetterneck, Telles, & Karsh, 2008; Metzger, Welebob, Bates, Lipsitz, & Classen, 2010; Nanji et al., 2011; Nebeker, Hoffman, Weir, Bennett, & Hurdle, 2005; Singh et al., 2009; Zhan, Hicks, Blanchette, Keyes, & Cousins, 2006). Unfortunately, unexpected consequences often come to the attention of healthcare personnel only after errors and patient safety hazards have emerged. These EHR-related safety concerns must be addressed by taking into account the complex sociotechnical context in which EHRs are deployed (Sittig & Singh, 2010).

In order to address the safety concerns raised by the rapid adoption of EHRs by hospitals, the Office of the National Coordinator for Health Information Technology (ONC) convened an expert panel to investigate the potential for unintended negative consequences and sponsored the 2011 Institute of Medicine report *Health IT and Patient Safety: Building Safer Systems for Better Care*. These efforts also spurred the Safety Assurance Factors for EHR Resilience (SAFER) project. The goal of the SAFER project was to develop self-assessment guides that healthcare organizations can use to proactively assess potential EHR-related safety problems in nine high-risk areas, one of which is CPOE, whether used in the inpatient or outpatient setting. The general plan for development, refinement, and beta-testing of the SAFER assessment guides has been described elsewhere (Singh, Ash, & Sittig, 2013). The SAFER guides are freely available on the ONC's website at http://www.healthit.gov/policy-researchers-implementers/safer.

In this article, we describe the development and field testing of recommendations for CPOE-specific risk assessment in the SAFER project.

MATERIALS AND METHODS

CPOE Guide Development

The rationale for the development of the SAFER guides was to enable proactive self-assessment to build system resilience around EHR safety. The development process for the CPOE-specific and other guides followed a series of common steps. We first conducted a literature search on CPOE and its effects on patient safety using MeSH (medical subject headings) search terms, such as *medical order entry systems* and *patient safety*, along with the following text words: *(computerized or computer-based) (physician or provider) order entry and (patient safety or errors or adverse events)*. All articles were reviewed for potential relevance based on the title and abstract. All relevant articles were subsequently reviewed in full. We also consulted with subject-matter experts in informatics, pharmacy, patient safety, human factors engineering, and

usability for additional literature and potential topics to be included in the guide. Based on this initial assessment, we drafted a set of approximately 250 items, each representing practices relevant to the safe use of CPOE. Three investigators (CVV, HS, DFS) with backgrounds in clinical medicine, patient safety, and informatics worked as a team to review and condense these items, removing redundant items as well as those related to other types of healthcare outcomes (e.g., efficiency). We then conducted preliminary validation of the items through five site visits lasting 1 to 3 days at small and large ambulatory practices and hospitals. Site visits included one-on-one interviews with a variety of personnel involved in the use of CPOE, such as clinicians, information technology professionals, pharmacists, informaticians, and quality improvement leaders. We made further revisions to the items on the basis of feedback from these informants, with a goal of maximizing the usefulness and interpretability of the items by involving individuals with differing types and degrees of expertise.

The resultant draft consisted of 22 checklist-type items that represented CPOE-related safety practices, with additional detailed descriptions of these practices and examples of how to operationalize them included in a supplementary appendix. For each item, respondents could indicate the degree of implementation of each practice at their respective sites. Possible responses included "not implemented," "partially implemented in some areas," "fully implemented in some areas," and "fully implemented in all areas."

Field Testing

We field tested the CPOE guide with chief medical informatics officers (CMIOs) at various institutions across the United States (Leviss, Kremsdorf, & Mohaideen, 2006). This group represented a highly knowledgeable population of informants, given their heavy involvement in CPOE implementation (Leviss et al., 2006). Following institutional review board approval, we purposefully recruited informants through the listserv of the Association of Medical Directors of Information Systems (AMDIS). One of the authors (CVV), as an AMDIS member, regularly monitored postings by the CMIO community and identified those who expressed some interest in CPOE or were involved in CPOE-related activities. Potential participants were contacted initially via e-mail with an explanation of the SAFER project and an invitation to evaluate the CPOE guide. We recruited nine individuals; no compensation was provided. Participants were asked to complete the assessment within the CPOE guide and then complete a structured interview by phone. One of the authors (CVV) conducted all the interviews, each lasting approximately 30 minutes. In addition to inquiring about the characteristics of the respondent's facility (e.g., bed size, EHR platform, teaching status), the interviewer administered nine structured interview questions (see Table 1). Responses were collated and presented as frequencies within each of the response categories. Free-text responses were reviewed for common themes and used to refine the content, organization, implementation, and use of the guides.

TABLE 1
CPOE Structured Interview Guide

1. How long did it take you to complete the CPOE guide?
2. Do you feel like the team that completed the guide was the correct team to do so? If no, how would you recommend identifying the correct team?
3. Do you feel that any important practices were left out? If yes, what was left out?
4. Were any of the practices redundant? If yes, provide more detail.
5. Do you feel that the guide was useful? In what ways do you find the guide useful?
6. What do you feel is the purpose of the guide?
7. Did you refer to the appendix for additional information/examples when completing the guide? If yes, did you find the appendix useful?
8. How frequently would your team be willing to complete the guide?
9. Do you have any other suggestions for how the guide could be improved?

RESULTS

Informant and Facility Characteristics

The nine respondents represented pediatric facilities (n = 2) and tertiary care adult, acute care hospitals (n = 7) that were geographically distributed across eight states in several regions of the United States. Institutions ranged in size from approximately 85 beds at one pediatric facility to 1,100 beds at an acute care hospital. Seven were teaching hospitals. The EHR platforms used at these facilities were Allscripts (n = 3), Epic (n = 3), Meditech (n = 2), and Cerner (n = 1). All systems were in clinical use, and all clinicians were trained in the CPOE features and functions.

EHR and CPOE system configuration and implementation processes across the nine facilities were widely heterogeneous. Most involved ancillary systems (i.e., pharmacy, laboratory, or radiology) from multiple vendors that were interfaced to create a best-of-breed, end-to-end solution. In addition, drug–patient age checking and dose-range checking were simply unavailable in some institutions, given the current state of their EHR systems.

Feasibility of CPOE Guide Completion

The modal completion time was 10 to 15 minutes, with a range of 5 to 30 minutes. Informants largely indicated that they felt comfortable answering the questions themselves. Two individuals sought additional input from pharmacy personnel. None of the informants indicated that any of the items were redundant with one another. About half the informants referred to the appendix of the guide for additional information and examples while completing the items.

Endorsement of CPOE-Related Safety Practices

Table 2 displays CMIOs' responses to each of the 22 recommended practices; responses varied across the entire spectrum from non- to full implementation. Only five recommended practices,

mostly involving basic CPOE functionality (items 4 and 5) and allergy checking (items 1 and 8), were fully implemented at all sites. Respondents suggested several additions to the recommended practices; these included items pertaining to (1) training requirements, such as "providers should be trained before they can enter orders"; (2) alert fatigue; that is, "interruptive alerts are used with discretion and only for certain high-risk, high-priority conditions"; (3) clinical decision support, as in "CDS interventions should be included in the CPOE guide"; (4) downtime, such as "downtime procedures should be included in the CPOE guide"; (5) unintended consequences; for example, "potential unintended consequences of CPOE should be monitored"; (6) monitoring, as in "the ability to track lifetime exposure to radiation should be included"; (7) alerts, such as "nonmedication duplicate order alerts should be included"; (8) mobility, or the ability to carry their EHR around with them (e.g., by iPhone or iPad), should be addressed; (9) integration across systems, such as "platform integration across the continuum of care (e.g., outpatient, emergency room, inpatient) should be emphasized"; and (10) orderable/test name synonyms or aliases, such as "CBC for complete blood count," should be mentioned.

Respondents raised specific concerns for drug–condition checking and drug-interaction-related alerts. They cited excessive firing of alerts as a common phenomenon and also reported that clinical decision support in their EHRs was overly simplistic. This led to such excessive levels of "noise" that many of these alerts were deactivated by the organization's clinical leadership.

Consensus around best practices was surprisingly low. For example, less than half of all respondents thought that requiring a physician to reenter his or her password to "sign" an order was beneficial. Furthermore, respondents commented that the question on corollary orders was vague, because it used the term *certain medications* without further clarification. They believed it was unclear how many corollary orders they would need to have in place before answering "4: fully implemented in all areas for all patients, processes, and staff." Because not all medications require corollary orders, it is not feasible to recommend that this occur for all types of medications.

Perceived Usefulness and Applicability of the Guide

When asked whether the guide was useful, all informants responded in the affirmative. One informant remarked specifically about the potential difficulty in implementing the recommended practices in community hospitals lacking dedicated informatics personnel. Other specific comments about the usefulness of the items included the following:

- "Better confidence that we're doing the right thing"
- "It represents best practices"
- "It made me think a lot about what we're doing and does it make things better"
- "If the community agrees on a standard, it gives the hospital ways to compare themselves"

TABLE 2
Frequencies of Endorsement of Practices to Improve Safety of CPOE

Recommended Practice	Not Implemented	Partially Implemented in Some Areas	Fully Implemented in Some Areas	Fully Implemented in All Areas
1. Coded allergen and reaction information (or No Known Allergies [NKA]) are entered and updated in the EHR prior to order entry.	—	—	—	9
2. Evidence-based order sets are available for common tasks/conditions and are updated on a regular basis, and usage is monitored.	—	1	2	6
3. User-entered orderable items are matched to (or can be looked up from) a list of standard terms.	—	1	—	8
4. EHR can cancel and acknowledge receipt of an order with lab, radiology, and pharmacy.	—	—	—	9
5. EHR is used for ordering medications, diagnostic tests, and procedures.	—	—	—	9
6. There is minimal use of free-text order-entry (i.e., data are entered and stored in coded form).	—	—	—	9
7. Order entry information is electronically communicated (i.e., via the computer/mobile messaging) to the appropriate people responsible for carrying out the order.	—	—	1	8
8. Drug-allergy interaction checking occurs at entry of new medication orders or new allergies.	—	—	—	9
9. Duplicate checking occurs for certain orders (excluding PRN medications).	—	—	1	8
10. Drug-condition checking occurs for important interactions between drugs and selected conditions.	2	1	2	4
11. Drug-patient age checking occurs for important age-related interactions.	2	2	2	3

12. Dose-range checking occurs before medication orders are submitted for dispensing (e.g., maximum dose amoxicillin 2-g oral tablets).	1	2	1	5
13. Only the most significant and actionable drug-drug interaction-related alerts, as determined by the facility, are presented to providers.	1	—	1	7
14. Clinicians are required to reenter their password, or a unique PIN, to "sign" or authenticate an order.	5	—	—	4
15. Corollary (or consequent) orders are automatically suggested by certain medication entries and are linked to and carried forward with the original order.	—	5	3	1
16. Users can access clinical reference materials, including institution-specific knowledge links, directly from the EHR.	—	1	3	5
17. The Leap Frog Test is taken to ensure safety of CDS.	5	—	—	4
18. Critical patient information is visible during the order-entry process.	—	1	—	8
19. The clinician is notified (e.g., by icon to signify nonformulary medication or send-out test) when additional steps (electronic or manual) are needed to complete the order being requested.	1	1	—	7
20. There is minimal use of abbreviations and acronyms, and when they are used, they are clearly spelled out in all on-screen or printed information displays.	—	2	—	7
21. Additional safeguards prevent errors related to prescribing of high-risk medications in the EHR.	—	1	1	7
22. Key metrics related to order-entry use are defined, measured, reported, and acted upon.	—	3	—	6

Note: The numbers in each column represent the total number of sites with that response.

Notably, however, many informants questioned whether all the items represented critical patient safety practices, for example, taking the Leapfrog test of clinical decision support. Some indicated that there were no immediate plans to implement certain items at their institutions. Additionally, one CMIO observed, "If it is a certified EHR, much of it [the recommended practices] is already available."

When asked about the perceived purpose of the guide, informants largely focused on its use for checking on the implementation of important or accepted practices. One informant viewed the guide as a means to "identify glaring holes and opportunities for improvement." When asked to comment on the appropriate frequency of reassessment, six CMIOs indicated that retaking the survey annually was reasonable, though one of them thought it might be less frequent if "at steady state" (i.e., CPOE has been fully implemented in all locations and physician utilization for all order types is stable at greater than 90%). One CMIO suggested a 2-year reassessment timeline, whereas another suggested variable reassessment intervals "depending on new regulations or safety concerns." Finally, one informant stated, "We wouldn't do it again, but it would be useful to submit data to a national processing center to get comparisons with how our hospital is doing compared to other institutions around the country."

Finally, when asked to identify additional opportunities for improving the guide, seven of the nine informants offered no further comments. One CMIO suggested that "the introduction might ask pharmacy to fill out some of the answers." Another CMIO suggested an additional question: "Have you had any patient safety events related to CPOE?"

The refined version of the combined CPOE and CDS SAFER Guide is available.

DISCUSSION

We developed and field tested a guide for proactive self-assessment of CPOE-related safety practices. On testing the guide with nine CMIOs at hospitals of varying sizes and geographical locations, we found that the completion of the self-assessment was feasible, requiring less than 30 minutes to complete. Although the assessment was designed to be completed by a multidisciplinary team, all but two respondents were able to answer the questions without additional input. Informants generally found the CPOE guide to be useful in outlining best practices, and most believed that an annual reassessment was reasonable.

Our field testing indicated that CMIOs varied considerably in their opinions as to what constitutes safe and effective CPOE use. Although none of the recommended practices were consid-ered redundant, informants had diver-gent opinions about their importance in many cases. For example, the require-ment to enter a unique personal identi-fication number (PIN) or login password to authenticate orders was nearly evenly split between non- and full implementation. The five CMIOs whose institutions did not require this practice believed that reentering a PIN

or password was redundant to logging into the EHR and was "a waste of time" for the provider, whereas others believed that this redundancy provided an important final check of order accuracy and the provider's ordering authority. Respondents were also divided in their perceptions of the utility of the Leapfrog Test, which "evaluates the ability of implemented CPOE systems to prevent the occurrence of medication errors that have a high likelihood of leading to adverse drug events" (Kilbridge, Welebob, & Classen, 2006, pg. 81; Metzger et al., 2010). The availability of corollary orders (item 15) was also problematic, with the majority of institutions not having fully implemented this practice. Unfortunately, to our knowledge there is no "official" list of medications that warrant corollary orders, although there is a list that has been successfully implemented (Overhage, Tierney, Zhou, & McDonald, 1997). Our findings underscore the importance of continual updates of EHR-related best practices as the use of and experience with EHRs grows.

Our field testing revealed useful feedback to improve the future implementation and use of the guide. We envisioned the guide might require input from multiple stakeholders. However, we learned that when multiple stakeholders are unable to participate in the self-assessment process, one individual (perhaps with knowledge and experience levels similar to CMIOs) may still be able to generate useful information. Furthermore, the original design of the SAFER project was to develop nine self-assessment guides, including one for CPOE and one addressing CDS. Based on the feedback from the CMIOs and the inherently close relationship between CPOE and embedded CDS, we combined the CDS and CPOE self-assessment guides, resulting in the addition of seven recommended, CDS-focused practices to the original CPOE guide. Because most of the clinical and patient safety benefits of CPOE are attributable to the effectiveness of CDS, it would be best to assess their safety and effectiveness together.

We also obtained useful information on improving the content of the guide items. In addition to holding varied opinions about the merits of recommended practices, many respondents considered our list incomplete and suggested additional topics not included in the original guide. Several additional topics that were mentioned (e.g., training; alert fatigue; unintended consequences, such as downtimes) were addressed in the examples that were included in the appendix of the original guide, so it is possible that they were overlooked by those who, by their own admission, may have only skimmed the contents of that section. Finally, the issue of downtime procedures is covered in a separate SAFER guide entitled "Contingency Planning for Electronic Health Record-Based Care Continuity" (Sittig, Gonzalez, & Singh, 2014). Due to the complex interactions of the many dimensions of EHR-enabled healthcare, it is likely that institutions or practices will need to use one or more of the additional eight guides to comprehensively assess their EHR-based system.

Issues related to wording came up often, and we used this feedback to improve some of the item content.

However, we needed to weigh some of the feedback on item wording, and we did not always make changes to specific items. For example, several respondents noted that certain recommended practices were worded as compound questions (e.g., "Evidence-based order sets are available for common tasks *and* are updated on a regular basis, *and* usage is monitored"). They wondered how this question could be answered if the order sets are in place but are not updated or usage is not monitored. Our team found this aspect of self-assessment to be challenging but believed that some compound questions would be necessary. This is because best practices often come as a bundle, wherein each bundled item needs to be satisfied independently in order to make the bundle effective. We further reviewed the use of compound questions, including "Key metrics related to order entry are defined, measured, reported, and acted upon." This was again determined to be a best practice bundle where each of the four facets is vital. We thus learned that future respondents need to be instructed that they must be performing all aspects of compound or bundled recommendations to receive "credit" for that practice.

Finally, several respondents noted that while they agreed with the importance of several recommendations (e.g., dose–range and drug–patient age checking), their EHRs as currently designed and developed were simply not able to perform those functions. In fact, this type of scenario was not uncommon during our preliminary validations of the various SAFER guides. Therefore, we note that to fully comply with the SAFER guide, EHR developers will need to identify and address specific functionality issues within their EHR offerings. This type of effort could gain momentum if a national body, such as the U.S. Department of Health and Human Services in conjunction with the ONC, could include specific CDS functionality in future EHR certification efforts by the ONC's Authorized Testing and Certification Bodies.

Several limitations of this study are worthy of mention. Although many medical informaticists are members of AMDIS, there are undoubtedly others who do not belong to this organization. Limiting our informants to those who have posted on the AMDIS listserv likely introduced a selection bias. Similarly, by only querying hospital CMIOs, we excluded feedback from institutions without a dedicated CMIO. While having a dedicated CMIO is a highly recommended practice, we acknowledge that, presently, most hospitals do not have such an individual (Wright et al., 2013). CMIOs are more likely to exist in organizations with a longer history of EHR deployment, yet it was the more recent and rapid adoption of EHRs that prompted the ONC to convene its expert panel and ultimately produce the SAFER guides. Seven of the nine institutions queried in this survey are teaching hospitals, and it is possible they are not representative of community facilities across the country. As these guides are being developed for use by a wide range of hospitals, including those without a CMIO and possibly with a recently installed EHR, we might have excluded potentially valuable comments from audiences that would be likely future

users of this guide. However, we anticipate that the guides we created will be useful sources of knowledge of best practices regardless of their ultimate users.

CONCLUSION

We have developed and field tested the SAFER CPOE self-assessment guide and found that the completion of the self-assessment is feasible and usually does not require much more than the CMIO's own knowledge of the organization. Although the 22 recommended safety practices were previously identified through a rigorous content review and expert opinion process, few were consistently implemented across facilities, and it was apparent that our informants held divergent opinions as to what constitutes best practices for CPOE-related safety. As CMIOs are likely to be the individuals advising their organizations, it would appear that full adoption of many recommended practices is unlikely until there is greater consensus about the merits of these and other safety practices. Additionally, EHR vendors will need to prioritize safe functionality of CPOE and CDS within the design of these systems so that best practices can have maximal reach and improve patient care. A CPOE-specific guide such as ours may provide a practical and actionable tool to stimulate further discussion and the development of best practices in this area.

NOTE

1. The views expressed in this article are those of the authors and do not necessarily represent the views of the U.S. Department of Veterans Affairs or the Office of the National Coordinator for Health Information Technology.

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PRACTITIONER APPLICATION

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The article by Vartian, Singh, Russo, and Sittig highlights yet again the need for a greater understanding of the scientific underpinnings of high reliability and the cultural changes necessary to make care safer. It comes as no surprise that the authors found that "EHR and CPOE system configuration and implementation processes across the nine facilities were widely heterogeneous" and that "most recommended practices were implemented inconsistently across facilities."

Over the past two decades, the healthcare field has made significant progress in improving care systems such as medication ordering and delivery, but we still have a long way to go to achieve the level of safety that other high-risk industries, such as commercial aviation, have reached. Imagine if a survey of the chief flight officers of nine airlines found that the airlines had not implemented all of the Federal Aviation Administration's rules for safe flight and, furthermore, they did not believe all the rules were necessary. Now imagine that these airlines are flying planes made by four different manufacturers—each making its own decisions about which safety devices to build into its planes—and that the planes are flown by pilots who believe they can pick and choose which rules to follow on the basis of their own beliefs about what works.

Such is the state of affairs in many U.S. hospitals today.

The reliability issue in healthcare is compounded by the fact that many leaders of hospitals have limited knowledge of human factors science and may not understand that automation, such as in electronic health records and computerized provider order entry systems, alone does not eliminate all errors. GBMC HealthCare has significantly improved reliability, but we still have work to do. Our board and senior nursing, physician, and administrative leaders are required to read John Nance's (2008) book *Why Hospitals Should Fly* to help accelerate cultural change. We developed a required course in patient safety for all of our employees to give them a basic understanding of the science of error mitigation. We created a robust error and near-miss reporting system and set annual goals for events reported and for reduction in actual incidents of harm. We use Lean daily management as a tool to drive standardized work, and we celebrate the accomplishments of local and organization-wide teams.

Vartian et al., and the other collaborators in the Safety Assurance Factors for EHR Resilience project, should be applauded for creating tools to help us implement technology such as CPOE effectively. Leaders of healthcare organizations must continue to breed a culture of humility and collaboration, which, along with curiosity about how to make things better, will create a more fertile environment for using these tools to achieve better care.

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