Final Progress Report to Agency for Healthcare Research and Quality

Title of Project

Assess Risk of Wrong Patient Errors in an EMR that Allows Multiple Records Open

Grant Award Number

7R21HS023704-04

Principal Investigator and Team Members

- Columbia University
  - PI: Jason Stuart Adelman, MD
  - Project Coordinators: Marina Sterling, Chelsea Redman
- Albert Einstein College of Medicine
  - Subaward PI: William Southern, MD, MS
  - Co-Investigator: Clyde Schechter, MD, PhD
- Brigham and Women's Hospital
  - Subaward PI: Gordon Schiff, MD
  - Co-Investigators: David Bates, MD, MSc, Adam Wright, PhD
- Institute for Safe Medication Practices
  - Consultant: Susan Paparella, MSN
- Northwestern University
  - Consultant: Bruce Lambert, PhD
- University of Illinois at Chicago
  - Consultant: William Galanter, MD, PhD
- University of Pennsylvania
  - Consultant: Ross Koppel, PhD

Organization

The Trustees of Columbia University in the City of New York

Inclusive Dates of Project

09/30/2014–09/29/2018

Federal Project Officer

Edwin Lomotan, MD

Acknowledgment of Agency Support

We would like to thank the Agency for Healthcare Research and Quality (AHRQ) for their generous support of this research, Dr. Ed Lomotan for his guidance and support of the project, and Ms. Nicole Williams for her assistance with grant administration.

1. STRUCTURED ABSTRACT

Purpose: To assess the risk of wrong-patient orders in an electronic health record (EHR) configuration limiting providers to one patient record open at a time versus a configuration allowing up to four records open concurrently.

Scope: National recommendations for the safe use of EHR systems call for limiting the number of patient records displayed at the same time to one. However, little evidence supports these recommendations.

Methods: We conducted a randomized comparative effectiveness trial in a large health system to compare the risk of wrong-patient orders in an EHR configuration limiting providers to one patient record open at a time (Restricted arm) versus a configuration allowing up to four records open concurrently (Unrestricted arm). The unit of analysis was the order session, defined as a series of orders placed consecutively by a single provider for a single patient. The primary outcome was wrong-patient order sessions, including at least one wrong-patient order identified using the Wrong-Patient Retract-and-Reorder measure.

Results: The trial included 3356 randomized providers who placed 12,140,298 orders in 4,486,631 order sessions for 543,490 patients. There was no significant difference in wrong-patient order sessions in the Restricted versus Unrestricted arm, overall (odds ratio [OR]: 1.03; 95% confidence interval [CI], 0.90 to 1.20; *P* = .60), in the emergency department (OR: 1.00; 95% CI, 0.83 to 1.20; *P* = .96), inpatient settings (OR: 0.99; 95% CI, 0.89 to 1.11; *P* = .86), or outpatient settings (OR: 0.94; 95% CI, 0.70 to 1.28; *P* = .71).

Key Words: Medical errors, patient safety, electronic health record, patient identification, wrong-patient errors

2. PURPOSE

The purpose of this randomized comparative effectiveness trial was to assess the risk of wrong-patient errors at the system level by comparing two electronic health record (EHR) settings: a configuration limiting providers to one patient record open at a time versus a configuration allowing up to four patient records open at once. We pursued the following specific aims:

1. Compare the risk of wrong-patient orders in a *restricted environment* that limited providers to one record open at a time versus an *unrestricted environment* that allowed up to four records open concurrently.
2. Examine the relationship between wrong-patient orders and the number of records open at the time of placing an order.

3. SCOPE

Background

Although computerized provider order entry (CPOE) is associated with a reduction in medical errors, when orders are placed electronically certain types of errors, including placing orders on the wrong patient, may occur more frequently. The danger of wrong-patient electronic orders was highlighted by one hospital's report that after implementing CPOE, medications were prescribed for the wrong patient several times per month. In 2003, the United States Pharmacopeia analyzed 7029 voluntarily reported medication errors over a 7-month period and found a mean of 9 wrong-patient orders at each of 120 participating institutions using CPOE. This report likely underestimated the extent of wrong-patient electronic orders, as voluntary reporting is known to be an unreliable method for identifying errors.

Dr. Jason Adelman, the Principal Investigator of this study, developed the **Wrong-Patient Retract-and-Reorder (RAR) Measure**,[1] the first Health IT Safety Measure endorsed by the National Quality Forum (NQF Measure #2723).[2,3] The Wrong-Patient RAR Measure is an automated, validated, and reliable measure to quantify the frequency of wrong-patient orders and test interventions to prevent them. The measure detects instances of one or more orders placed for a patient that are retracted (cancelled) within 10 minutes, and then placed by the same provider for a different patient within the next 10 minutes (Figure 1). The Wrong-Patient RAR Measure is programmed as an electronic query and run retrospectively against every order from a data warehouse or replica server. The source is log data recorded in the EHR during the course of clinical care, thereby supplying data on millions of orders per year in a large health system. Numerous healthcare

organizations, using the major electronic health record systems, have successfully deployed the measure to capture wrong-patient orders in inpatient, emergency department, and ambulatory settings.

In the validation study, real-time confirmatory telephone interviews with providers demonstrated that the measure correctly identified near-miss, wrong-patient orders in 170 of 223 cases, yielding a positive predictive value of 76.2%.[1] The measure identified 5246 orders placed on the wrong patient over a 1-year period in a large academic medical center, translating to 58 wrong-patient orders per 100,000 orders.[1] In that year, approximately 1 in 6 providers placed an order for the wrong patient, and 1 in 37 hospitalized patients had an order placed for them that was intended for another patient. These errors occurred among attending physicians (60 errors per 100,000 orders), nurse practitioners and physician assistants (74 errors per 100,000 orders), and pharmacists (67 errors per 100,000 orders).[1] Two subsequent studies of wrong-patient orders conducted in the emergency departments of different health systems using different EHRs found an average of 84 to 202 errors per 100,000 orders.[4,5]

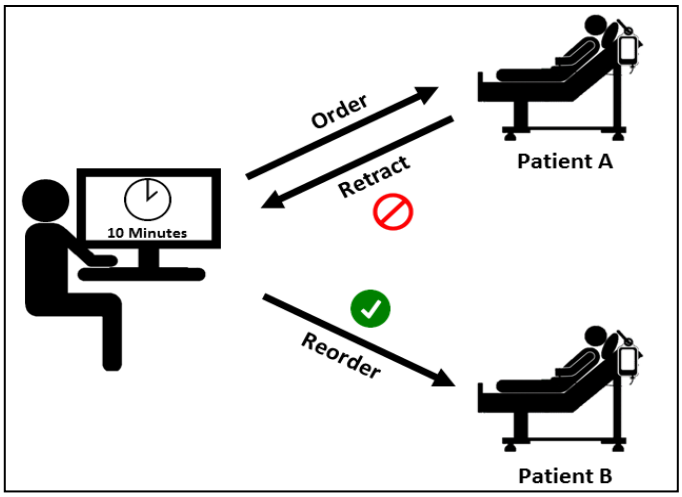


Figure 1. Wrong-Patient Retract-and-Reorder Measure.

These studies using automated surveillance to identify wrong-patient orders demonstrated the prevalence to be significantly higher than previously thought. This volume of near-miss, wrong-patient orders is vastly greater than estimates reported in studies using voluntarily reported errors as the outcome,[6-8] enabling researchers to test interventions to prevent this type of error.

Context

The hazard of wrong-patient orders persists despite a longstanding Joint Commission National Patient Safety Goal requiring proper patient identification,[9] and the use of patient identification interventions implemented within EHR systems such as ID verification alerts[1,5] and patient photographs.[10] In efforts to prevent wrong-patient errors and promote the safe use of health information technology nationally, the Office of the National Coordinator for Health Information Technology (ONC)[11] and The Joint Commission[12] issued recommendations that health systems limit the number of records displayed in the EHR to one at a time. However, these recommendations cite expert opinion,[11,13,14] as no evidence exists that multiple patient records open at once in the EHR increases the risk of wrong-patient errors. There have been several articles that warn of this potential risk,[10,15,16] but none of these studies were designed to determine whether there was an association between reported errors and multiple records having been open.

We conducted a national survey of Chief Medical Information Officers to determine what percentage of facilities comply with the recommendations and found wide variation in practice. Among inpatient and outpatient facilities using EHR systems with the capability to have multiple patient records open concurrently, 44% allowed three or more records open at once, 38% restricted to one record open, and 17% allowed up to two records open.[17] Respondents who reported allowing multiple records open cited the need for efficiency, while those who reported restricting users to a single record cited safety concerns about wrong-patient errors. Respondents who chose to “hedge” by allowing up to two records open reported seeking to strike a balance between efficiency and safety.

Given the lack of rigorous evidence, as well as the lack of consensus, we conducted a randomized comparative effectiveness trial to test the hypothesis that use of a *restricted* configuration, limiting providers to one patient record open at a time, would result in significantly fewer wrong-patient orders than an *unrestricted* configuration allowing up to four records open. The relationship between the number of patient records open in an EHR and the risk of wrong-patient errors needs to be established to inform decision-making and national guidance on how to safely implement CPOE systems. Given the widespread adoption of CPOE in inpatient and outpatient settings, the decision about how many records to allow providers to open at once in EHRs has potentially far-reaching implications for patient safety as well as usability.

Settings

The trial was conducted from October 2015 to April 2017 at Montefiore, a large academic medical center and regional health system in New York that utilized EpicCare (Epic Systems Corporation, Verona, WI) during the trial period. Trial sites included four hospitals with a total of 1536 beds, five emergency departments, and 144 outpatient facilities. The study protocol was approved by the Institutional Review Boards of Albert Einstein College of Medicine and Columbia University Irving Medical Center.

Participants

Providers. Any provider who places an electronic order can potentially place an order on the wrong patient. We therefore included in the study all providers with the authority to place electronic orders. Providers were excluded if their workflow either 1) had a defined requirement to open two patient records simultaneously (e.g., mother-infant services), or 2) bypassed the standard order entry process and therefore would not be captured by the outcome measure (e.g., radiologists).

Patients. Since all patients are at risk for wrong-patient orders, all orders placed by randomized providers for all patients during the trial period were included in the analysis.

As the study posed no more than minimal risk and did not involve any procedures for which written consent is normally required, and all data were collected as part of routine clinical care and extracted retrospectively at the end of the trial period, the IRB waived informed consent for patients and providers, per the code of Federal Regulations Title 45, Part 46.116 (d). To protect confidentiality, all patient and provider identifiers were replaced by pseudo-identifiers.

4. METHODS

Study Design

We conducted a randomized comparative effectiveness trial to test the hypothesis that use of a *restricted* configuration, limiting providers to one patient record open at a time, would result in significantly fewer wrong-patient orders than an *unrestricted* configuration allowing up to four records open. All inpatient, emergency department, and outpatient providers were randomized in a 1:1 ratio to either a maximum of one patient record open at a time (Restricted arm) or a maximum of four records open at once (Unrestricted arm). An information technology specialist responsible for assigning user templates in the EHR performed the randomization. A computerized random number generator was used to create a group assignment for each user at the time of randomization, thus ensuring concealed allocation and the inability to predict future assignments. Then, each provider was manually assigned to one of two EHR user-role templates that differed only in the number of patient records allowed open per trial arm. Providers newly hired after the start of the trial were randomly assigned to trial arm using the same procedure when being issued a new user logon for the EHR.

Interventions

In the Restricted arm, providers could open and view only one patient record at a time, with the patient's name displayed in a single "tab" at the top of the computer screen; the open tab had to be closed before a different patient's record could be opened. In the Unrestricted arm, providers could open and view up to four records at once, with patients' names displayed in separate tabs for each patient along the top of the screen. In both the Restricted and Unrestricted arms, the active patient's name, age, sex, date of birth, location, and attending physician of record were displayed in the banner at the top of the screen.

Measures

Clustering of Orders within Order Sessions. If a provider begins placing orders in the wrong patient's record, there is the possibility that several such orders will be placed and then retracted together. Therefore, individual orders do not represent independent opportunities for errors to occur. Orders are clustered within order sessions, defined as a series of orders placed consecutively by a single provider for a single patient that begins with opening that patient's order file and terminates when an order is placed on another patient or after 60 minutes, whichever comes first. Thus the order session, rather than each order,

represents an independent opportunity for a wrong-patient error to occur. Therefore, the unit of analysis was the order session.

Primary Outcome. The primary outcome measure, the Wrong-Patient RAR measure, is an electronic query run retrospectively against every order placed during the study period to identify instances in which one or more orders placed for a patient were retracted (cancelled) by the same provider within 10 minutes, and then reordered by the same provider for a different patient within the next 10 minutes (RAR events). The primary outcome is wrong-patient order sessions, defined as order sessions that include a wrong-patient RAR event identified by the Wrong-Patient RAR measure.

Secondary Outcomes. Secondary outcomes consisted of the following: 1) provider utilization of the multiple records capability, i.e., the proportion of orders placed when one, two, three, or four records were open; 2) frequency of wrong-patient orders with one, two, three, or four records open; 3) productivity measures, including the number of orders placed per provider per day, and the number of patients for whom orders were placed per provider per day; and 4) efficiency measures using a 2-month sample of log data recorded in the EHR system, including the number of mouse clicks, key presses, computer logins, screen switches, and time on the system. For secondary outcomes 1 and 2, an electronic log was created that recorded the number of records open at the time each order was placed.

Data Sources/Collection

We extracted data for all orders placed by randomized providers during the trial period. Data for each order, including provider, patient, order session, and order characteristics (below), were extracted retrospectively from the health system data warehouse at the end of the trial period. Preset batch orders (e.g., for vaccines) were excluded from the analysis, as these orders are not under the control of individual providers.

Provider-level characteristics: type of ordering provider (attending, resident, physician assistant, nurse practitioner, pharmacist, or other), and total number of orders placed during the study period (a measure of the frequency with which the provider uses the system).

Patient-level characteristics: age, gender, race, ethnicity, unit, and date and time of admission.

Order-session level characteristics: location of the order session (emergency department, medical-surgical unit, intensive care unit, labor and delivery, pediatrics, other specialty units).

Order level characteristics: type of order (medication, imaging, nursing order, procedure, other), date and time of order, date and time of retraction, and number of patient records open at the time the order was placed.

Statistical Analysis

The primary analysis of the randomized trial was intention-to-treat, with each provider generating a cluster of order sessions. The primary outcome variable was dichotomous, indicating whether or not each order session contained a wrong-patient RAR event. To determine the effect of trial arm on wrong-patient orders, we constructed random effects logistic regression models with wrong-patient order sessions as the outcome, and randomization arm as the independent variable, using provider as a random intercept to account for clusters of order sessions within providers. We estimated the effect using the odds ratio (OR) and its 95% confidence interval (CI), and used the Wald test with a two-sided *alpha* of .05. For subgroup analyses, we prespecified clinical settings, including emergency department, inpatient, and outpatient locations, and further specified subgroups by inpatient unit, including medical/surgical, critical care, pediatrics, and obstetrics units. In subgroup analyses, we constructed similar mixed effects models in each predefined subgroup, with a separate model including an interaction term to test the significance of treatment effects across subgroups, using the Wald test of significance. The primary outcome is reported as the number of wrong-patient order sessions per 100,000 order sessions.

Because of administrative errors, some providers were not assigned to the trial arm to which they were randomized. Therefore, we repeated all assessments in as-treated analyses (i.e., according to intervention received) such that each order or order session was characterized by the provider's configuration at the time the orders were placed.

In the analysis of provider utilization of the multiple records capability in the Unrestricted arm, we reported the percentage of all orders placed when one, two, three, or four records were open at the time of ordering, overall and stratified by clinical setting. Similarly, we reported the frequency of wrong-patient orders per 100,000 when one, two, three, or four records were open at the time of ordering with 95% binomial confidence intervals, overall and by clinical setting. These analyses used the order as the unit of analysis (rather than the order session), because a provider could open or close patient records while placing a series of orders during a single order session. Measures of productivity and efficiency are reported as median per provider per day with interquartile range, as these values were not normally distributed. Differences between groups were tested using rank sum tests.

Limitations

Our study has several limitations. First, although this was a multi-site trial that included hospitals, emergency departments, and outpatient settings, it was conducted within a single health system using a single EHR platform; therefore, results may not be generalizable to other medical centers and EHR systems. Second, we assessed only one type of error using a measure of near-miss events that are detected and corrected before reaching the patient. However, near-miss errors follow the same causal pathway as errors that cause harm, and their use to test safety interventions in healthcare is endorsed by the major organizations dedicated to patient safety.[18-22]

5. RESULTS

Principal Findings

A total of 3356 providers were randomized and included in the intention-to-treat analysis, 1669 in the Restricted arm and 1687 in the Unrestricted arm. The analysis included a total of 12,140,298 orders, in 4,486,631 order sessions, placed for 543,490 patients. Provider characteristics were well-balanced between trial arms (Table 1). Order and patient characteristics are reported in Tables 2 and 3, respectively.

Table 1. Provider Characteristics

	No. (%) of Providers	
	Restricted[a] (n = 1669)	**Unrestricted[b] (n = 1687)**
Age, mean (SD), y	42.9 (12.7)	43.2 (12.3)
Experience at study site, mean (SD), y	6.4 (6.0)	6.6 (6.0)
Sex,		
Female	935 (56.0)	959 (56.8)
Male	734 (44.0)	728 (43.2)
Provider type		
Attending physician	806 (48.3)	814 (48.3)
House staff	529 (31.7)	542 (32.1)
Mid-level[c]	334 (20.0)	331 (19.6)
Primary practice area		
Outpatient	835 (50.0)	876 (51.9)
Inpatient		
Medical/surgical	335 (20.1)	312 (18.5)
Pediatrics	52 (3.1)	70 (4.1)
Obstetrics	35 (2.1)	32 (1.9)
Critical care	8 (1.7)	18 (1.1)
Other	116 (7.0)	105 (6.2)
Emergency department	151 (9.0)	135 (8.0)
Unclassified	117 (7.0)	139 (8.2)

[a] Restricted, configuration limiting to one record open at a time.
[b] Unrestricted, configuration allowing up to four records open concurrently.
[c] Mid-level providers include nurse practitioners and physician assistants.

Table 2. Order Characteristics

	No. (%) of Orders	
	Restricted (n = 5,856,992)	**Unrestricted (n = 6,283,306)**
Order Type		
Medications	2,630,170 (44.9)	2,888,009 (46.0)
Labs	1,836,048 (31.4)	1,911,116 (30.4)
Imaging	253,922 (4.3)	253,732 (4.0)
Other	1,136,852 (19.4)	1,230,449 (19.6)

Table 3. Patient Characteristics

	No. (%) of Patients (N = 543,490)
Age, mean (SD), y	38.4 (4.2)
Sex	
Female	324,848 (59.8)
Male	218,642 (40.2)
Race/Ethnicity	
Black	159,026 (29.3)
White	65,240 (12.0)
Hispanic/Latino	123,464 (22.7)
Other/Unknown	195,760 (36.0)

Primary Outcome

Intention-to-Treat Analysis

Overall, there was no significant reduction in wrong-patient orders in the Restricted versus Unrestricted arm. The proportion of wrong-patient order sessions in the Restricted versus Unrestricted arms was 90.7 versus 88.0 per 100,000 order sessions, respectively (OR 1.03; 95% CI, 0.90 to 1.20; *P* = .60) (Table 4). Similarly, in subgroup analyses, we failed to find significantly fewer wrong-patient order sessions in the Restricted versus Unrestricted arm in any clinical setting examined, including the emergency department (OR 1.00; 95% CI, 0.83 to 1.20; *P* = .96), inpatient settings (OR 0.99; 95% CI, 0.89 to 1.11; *P* = .86), or outpatient settings (OR 0.94; 95% CI, 0.70 to 1.28; *P* = .71). Furthermore, subgroup analyses in inpatient medical/surgical, critical care, pediatrics, and obstetrics units did not show significantly fewer wrong-patient order sessions in the Restricted versus Unrestricted arm. Descriptive, order-level analysis of wrong-patient orders is presented in Table 5.

As-Treated Analysis

As a result of administrative errors, a total of 400 providers were not assigned to the trial arm to which they were randomized: 305 were assigned to the opposite arm at the beginning of the trial and remained in that arm throughout (185 randomized to Restricted, 120 randomized to Unrestricted); 95 switched arms during the trial (84 randomized to Restricted, 11 randomized to Unrestricted). Consistent with the intention-to-treat analysis, we did not find significantly fewer wrong-patient order sessions in the Restricted versus the Unrestricted arm in the as-treated analysis, overall (OR 1.03; 95% CI, 0.89 to 1.19; *P* = .68) or in any clinical setting. Provider characteristics and randomized trial results for the as-treated analysis are reported in the Tables 6 and 7, respectively); as-treated descriptive analysis of wrong-patient orders is presented in Table 8.

Secondary Outcomes

Provider Utilization in the Unrestricted Arm

In the Unrestricted arm, providers placed 64% of all orders with one record open; however, provider utilization of the multiple records capability while placing orders varied across clinical settings. For example, 33% of emergency department orders, 17% of inpatient orders, and 2% of outpatient orders were placed with

four records open (Figure 2). The frequency of RAR events with one, two, three, and four records open overall and by clinical location are shown in Table 9.

Provider Productivity and Efficiency

For measures of productivity, we found no significant differences between the Restricted and Unrestricted arms in median number of orders placed per provider per day (12.1 versus 12.2, respectively) and median number of patients for whom orders were placed per provider per day (4.3 versus 4.2, respectively) (Table 10). For measures of efficiency, there were no differences observed between trial arms, except for median number of key presses per provider per day (2784 Restricted versus 2959 Unrestricted, $P < .0005$). (The difference of 175 key presses between trial arms is approximately the length of the previous sentence.)

Discussion

In this large randomized comparative effectiveness trial, we did not find a significant difference in wrong-patient orders among providers limited to open one record at a time in the EHR compared to those allowed to open up to four records concurrently. Furthermore, we found no significant difference in any clinical setting that we examined in either the intention-to-treat or as-treated analyses. To our knowledge, this is the first trial to provide rigorous evidence that configuring an EHR to limit the number of patient records open to one at a time does not lessen the risk of wrong-patient errors or, conversely, that a configuration allowing as many as four records open concurrently does not increase the risk of wrong-patient errors. These results are at odds with expert opinion-based national patient safety recommendations to configure EHRs to limit the number of patient records that can be displayed at the same time to one.[11]

It has been assumed by some that allowing multiple records open in the EHR creates a hazardous environment where switching between patient records would potentially lead to confusion and errors, based on limited anecdotal evidence.[15,16,23] The only prior study evaluating the safety of multiple records in an EHR was an interrupted time series analysis in the emergency department of a large academic medical center, which demonstrated no significant decrease in wrong-patient medication orders by limiting the maximum number of records from four to two, and no increase after transitioning back from two to four records.[4] Although that study was limited to the emergency department and used a quasi-experimental design, the findings are consistent with the results of this randomized trial conducted in diverse clinical settings, in a different health system, and using a different EHR.

This trial provides novel insights into the utilization of the multiple records capability. In the Unrestricted arm, given the discretion to open up to four records, providers placed the majority of orders with one record open. However, providers in the emergency department placed nearly two-thirds of orders with two or more records open, and of all clinical settings placed the highest proportion of orders with the maximum of four records open. Emergency departments are considered high-risk clinical settings as providers care for multiple acutely ill patients concurrently, many of whom require complex treatment in a fast-paced environment characterized by frequent interruptions.[24-27] Because of the demands of the environment, and the fact that providers in the emergency department commonly had multiple records open when placing orders, one might expect that limiting to one record would have the most benefit in this setting. However, our results in this setting showed no difference in wrong-patient orders between trial arms, with an odds ratio of 1.0. This finding demonstrates that even in complex, high-volume settings where providers continually switch between patients,[28-32] the ability to open multiple records did not increase the risk of wrong-patient orders.

In contrast to results of the randomized trial, findings in the Unrestricted arm suggest an increasing frequency of wrong-patient errors with two or more records open at the time of placing orders. These conflicting results demonstrate a classic case of the effects of confounding, i.e., one or more unmeasured covariates associated with both the number of records open and the outcome of wrong-patient orders. A recent direct observation study demonstrated that multitasking and interruptions increased the rate of prescribing errors;[26] these factors may be the unmeasured confounders in our study. Furthermore, in our prior research, providers identified interruption as the primary cause of wrong-patient order errors in 81% of cases, further supporting the hypothesis that interruptions may be a potential confounder. The impact of multitasking, interruptions, and other potential human factors failure modes on the risk of wrong-patient orders warrants further investigation.[33]

Conclusions and Implications

We found no evidence that an EHR configuration restricting providers to open only one patient record at a time lessened the risk of wrong-patient errors. These findings do not support the expert opinion-based national recommendations to limit the number of records allowed open in EHRs to one at a time,[11,12] and suggest that health systems may configure EHRs to allow multiple records open without compromising safety. Furthermore, this trial underscores the importance of conducting randomized trials, when feasible, to evaluate safety interventions and recommendations.

These results have far-reaching implications for patient safety as well as provider satisfaction (see **Addendum** below). Recent national data indicate that 96% of U.S. hospitals[34] and 78% of office-based physicians[35] have certified EHRs. With more than 1 million physicians, physician assistants, and nurse practitioners in the U.S. healthcare workforce[36] and near universal adoption of EHR systems, EHR usability is receiving increasing attention. Our results suggest that health systems have flexibility in configuring their EHRs to accommodate the needs of their organization and of particular clinical settings. Furthermore, the Wrong-Patient Retract-and-Reorder Measure, the primary outcome measure in this study, can be used to monitor wrong-patient orders over time and as changes are implemented in EHR systems, as recommended by ONC.[11]

6. LIST OF PUBLICATIONS

Adelman JS, Berger MA, Rai A, et al. A national survey assessing the number of records allowed open in electronic health records at hospitals and ambulatory sites. J Am Med Inform Assoc 2017 Sep;24:992-995. PMID: 28419267.

Kannampallil TG, Manning JD, Chestek DW, et al. Effect of number of open charts on intercepted wrong-patient medication orders in an emergency department. J Am Med Inform Assoc 2018 Jun;25:739-743. PMID: 29025090.

Adelman JS, Applebaum JR, Schechter CB, et al. Wrong-Patient Errors in an Electronic Health Record Configured to Allow a Maximum of One vs Four Patient Records Open: A Randomized Comparative Effectiveness Trial. Submitted to JAMA, December 14, 2018.

Publications in Development

Provider Utilization of Multiple Records Capability in an EHR: Examination of Provider Practice across Clinical Settings.

Efficiency and Productivity of Providers Using an EHR Configured for a Maximum of One versus Four Patient Records Open.

Risk of Wrong-Patient Orders with a Maximum of Four Records Open in an EHR: Confounding in a Randomized Trial.

Provider Satisfaction Using an EHR Configured for a Maximum of One versus Four Patient Records Open (quantitative survey results).

Provider Perceptions of Safety and Efficiency of an EHR Configured for a Maximum of One versus Four Patient Records Open: A Qualitative Analysis (qualitative survey results).

Table 4. Results of Randomized Comparative Effectiveness Trial: Wrong-Patient Order Sessions (Intention-to-Treat Analysis)

	No. of Order Sessions					
	Restricted	Unrestricted	Odds Ratio (95% CI)	Restricted Better	Unrestricted Better	*P* value
Overall						
Wrong-patient order sessions per 100,000	**90.7**	**88.0**	1.03 (0.90 to 1.20)			.60
Wrong-patient order sessions	1980	2026				
Total order sessions	2,183,365	2,303,266				
Emergency department						
Wrong-patient order sessions per 100,000	**157.8**	**161.3**	1.00 (0.83 to 1.20)			.96
Wrong-patient order sessions	560	576				
Total order sessions	354,882	357,047				
Inpatient						
Wrong-patient order sessions per 100,000	**185.6**	**185.1**	0.99 (0.89 to 1.11)			.86
Wrong-patient order sessions	1324	1340				
Total order sessions	713,417	723,746				
Medical/Surgical						
Wrong-patient order sessions per 100,000	**187.9**	**187.8**	0.98 (0.85 to 1.12)			.73
Wrong-patient order sessions	940	879				
Total order sessions	500,338	467,941				
Critical care						
Wrong-patient order sessions per 100,000	**247.8**	**258.2**	1.04 (0.79 to 1.36)			.78
Wrong-patient order sessions	161	216				
Total order sessions	64,979	83,662				
Pediatrics						
Wrong-patient order sessions per 100,000	**122.5**	**139.2**	1.00 (0.68 to 1.46)			1.00
Wrong-patient order sessions	65	111				
Total order sessions	53,074	79,726				
Obstetrics						
Wrong-patient order sessions per 100,000	**201.1**	**197.1**	0.92 (0.61 to 1.38)			.68
Wrong-patient order sessions	85	78				
Total order sessions	42,272	39,575				
Outpatient						
Wrong-patient order sessions per 100,000	**7.9**	**8.2**	0.94 (0.70 to 1.28)			.71
Wrong-patient order sessions	86	97				
Total order sessions	1,082,855	1,176,344				

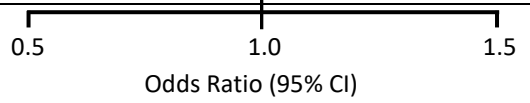


Table 5. Wrong-Patient Orders (Intention-to-Treat Analysis)

	No. of Orders	
	Restricted[a]	**Unrestricted[b]**
Overall		
Wrong-patient orders per 100,000	**52.2**	**48.0**
Wrong-patient orders	3058	3015
Total orders	5,856,992	6,283,306
Emergency department		
Wrong-patient orders per 100,000	**88.6**	**86.0**
Wrong-patient orders	980	978
Total orders	1,106,168	1,137,774
Inpatient		
Wrong-patient orders per 100,000	**89.5**	**86.7**
Wrong-patient orders	1940	1896
Total orders	2,166,764	2,186,305
Medical/Surgical		
Wrong-patient orders per 100,000	**91.6**	**87.5**
Wrong-patient orders	1387	1228
Total orders	1,513,368	1,403,712
Critical care		
Wrong-patient orders per 100,000	**117.7**	**120.8**
Wrong-patient orders	215	301
Total orders	182,698	249,252
Pediatrics		
Wrong-patient orders per 100,000	**54.4**	**58.6**
Wrong-patient orders	96	143
Total orders	176,601	243,890
Obstetrics		
Wrong-patient orders per 100,000	**103.1**	**115.3**
Wrong-patient orders	143	149
Total orders	138,681	129,270
Outpatient		
Wrong-patient orders per 100,000	**4.8**	**4.5**
Wrong-patient orders	119	128
Total orders	2,493,182	2,820,934

[a] Restricted, configuration limiting to one record open at a time.
[b] Unrestricted, configuration allowing up to four records open concurrently.

Table 6. Provider Characteristics (As-Treated Analysis)

Characteristic	No. (%) of Providers		
	Restricted[a] (n = 1520)	Unrestricted[b] (n = 1741)	Varied[c] (n = 95)
Age, mean (SD), y	42.9 (12.7)	43.4 (12.4)	41.2 (10.5)
Experience at study site, mean (SD), y	6.5 (6.0)	6.7 (6.0)	4.5 (5.5)
Sex			
Female	863 (56.8)	979 (56.2)	52 (54.7)
Male	657 (43.2)	762 (43.8)	43 (45.3)
Provider type			
Attending physician	728 (47.9)	844 (48.5)	48 (50.5)
House staff	485 (31.9)	562 (32.3)	24 (25.3)
Mid-level[d]	307 (20.2)	335 (19.2)	23 (24.2)
Primary practice area			
Outpatient	764 (50.3)	895 (51.4)	52 (54.7)
Inpatient			
Medical/surgical	327 (21.5)	310 (17.8)	10 (10.5)
Pediatrics	59 (3.9)	63 (3.6)	0 (0)
Obstetrics	25 (1.6)	39 (2.2)	3 (3.2)
Critical care	25 (1.6)	20 (1.1)	1 (1.1)
Other	105 (6.9)	107 (6.1)	9 (9.5)
Emergency department	126 (8.3)	149 (8.6)	11 (11.6)
Unclassified	89 (5.9)	158 (9.1)	9 (9.5)

[a] Restricted, configuration limiting to one record open at a time.
[b] Unrestricted, configuration allowing up to four records open concurrently.
[c] These providers switched between arms at least once during the course of the trial period.
[d] Mid-level providers include nurse practitioners and physician assistants.

Table 7. Results of Randomized Comparative Effectiveness Trial: Wrong-Patient Order Sessions (As-Treated Analysis)

	No. of Order Sessions					
	Restricted	Unrestricted	Odds Ratio (95% CI)	Restricted Better	Unrestricted Better	*P* value
Overall						
Wrong-patient order sessions per 100,000	**90.9**	**87.8**	1.03 (0.89 to 1.19)			.68
Wrong-patient order sessions	1934	2072				
Total order sessions	2,127,162	2,359,469				
Emergency department						
Wrong-patient order sessions per 100,000	**162.1**	**157.2**	1.05 (0.87 to 1.25)			.62
Wrong-patient order sessions	547	589				
Total order sessions	337,364	374,565				
Inpatient						
Wrong-patient order sessions per 100,000	**183.6**	**187.1**	0.97 (0.86 to 1.08)			.57
Wrong-patient order sessions	1295	1369				
Total order sessions	705,368	731,795				
Medical/Surgical						
Wrong-patient order sessions per 100,000	**189.8**	**185.8**	1.01 (0.89 to 1.16)			.83
Wrong-patient order sessions	942	877				
Total order sessions	496,254	472,025				
Critical care						
Wrong-patient order sessions per 100,000	**225.6**	**275.0**	0.87 (0.66 to 1.14)			.32
Wrong-patient order sessions	145	232				
Total order sessions	64,279	84,362				
Pediatrics						
Wrong-patient order sessions per 100,000	**112.2**	**150.5**	0.73 (0.50 to 1.06)			.10
Wrong-patient order sessions	70	106				
Total order sessions	62,373	70,427				
Obstetrics						
Wrong-patient order sessions per 100,000	**208.0**	**192.7**	1.04 (0.69 to 1.57)			.85
Wrong-patient order sessions	72	91				
Total order sessions	34,617	47,230				
Outpatient						
Wrong-patient order sessions per 100,000	**8.2**	**8.1**	0.98 (0.72 to 1.33)			.90
Wrong-patient order sessions	86	97				
Total order sessions	1,054,519	1,204,680				

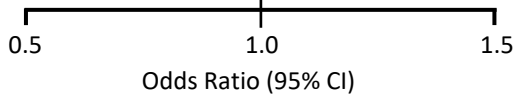
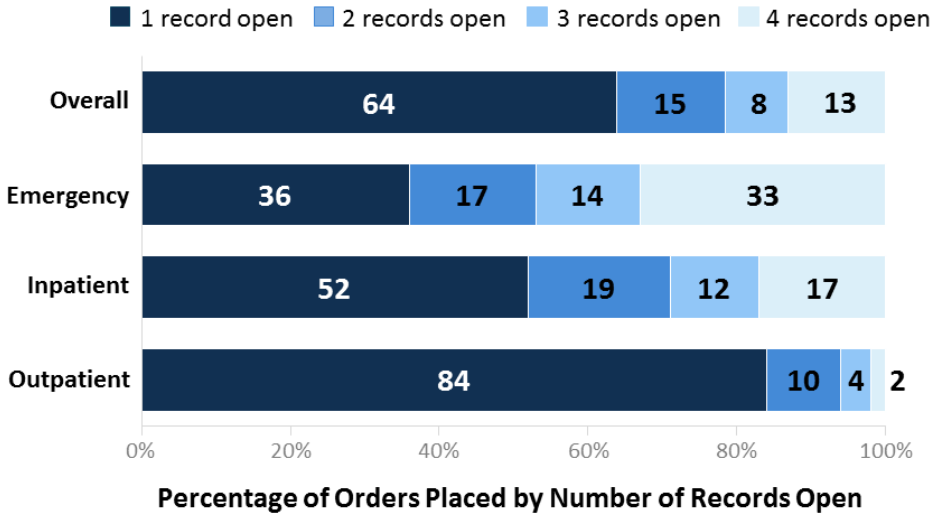


Table 8. Wrong-Patient Orders (As-Treated Analysis)

	No. of Orders	
	Restricted	**Unrestricted**
Overall		
Wrong-patient orders per 100,000	**52.1**	**48.2**
Wrong-patient orders	2982	3091
Total orders	5,724,389	6,415,909
Emergency department		
Wrong-patient orders per 100,000	**90.7**	**84.1**
Wrong-patient orders	966	992
Total orders	1,064,611	1,179,331
Inpatient		
Wrong-patient orders per 100,000	**88.2**	**88.1**
Wrong-patient orders	1884	1952
Total orders	2,137,109	2,215,960
Medical/Surgical		
Wrong-patient orders per 100,000	**93.7**	**85.3**
Wrong-patient orders	1408	1207
Total orders	1,502,711	1,414,369
Critical care		
Wrong-patient orders per 100,000	**99.2**	**134.3**
Wrong-patient orders	181	335
Total orders	182,506	249,444
Pediatrics		
Wrong-patient orders per 100,000	**45.8**	**66.9**
Wrong-patient orders	92	147
Total orders	200,712	219,779
Obstetrics		
Wrong-patient orders per 100,000	**106.0**	**111.2**
Wrong-patient orders	121	171
Total orders	153,767	114,184
Outpatient		
Wrong-patient orders per 100,000	**4.8**	**4.5**
Wrong-patient orders	118	129
Total orders	2,435,340	2,878,776

[a] Restricted, configuration limiting to one record open at a time.
[b] Unrestricted, configuration allowing up to four records open concurrently.

Figure 2. Provider Utilization: Orders Placed with One, Two, Three, or Four Records Open in the Unrestricted Arm



	No. of Orders Placed			
	1 record	2 records	3 records	4 records
Overall	4,090,901	941,329	535,162	848,517
Emergency department	422,013	201,485	165,514	390,319
Inpatient	1,153,459	421,042	257,462	383,997
Outpatient	2,424,894	298,413	99,475	55,994

Table 9. Wrong-Patient Orders with One, Two, Three, or Four Records Open in the Unrestricted Arm

	No. of Records in Use			
	1 record	2 records	3 records	4 records
Overall				
Wrong-patient orders per 100,000	**29.2**	**68.3**	**86.1**	**102.5**
95% CI	27.6–30.9	62.9–74.1	78.0–94.8	95.5–109.8
Wrong-patient orders	1220	577	414	804
Emergency department				
Wrong-patient orders per 100,000	**65.6**	**93.5**	**111.6**	**95.3**
95% CI	58.2–73.8	80.2–108.4	95.4–129.7	85.6–105.8
Wrong-patient orders	282	176	169	351
Inpatient				
Wrong-patient orders per 100,000	**65.2**	**106.1**	**108.7**	**132.6**
95% CI	60.8–69.8	95.7–117.4	95.4–123.3	120.7–145.4
Wrong-patient orders	828	376	240	452
Outpatient				
Wrong-patient orders per 100,000	**4.2**	**8.1**	**4.2**	**1.8**
95% CI	3.4–5.1	5.2–12.2	1.1–10.8	0.0–10.3
Wrong-patient orders	100	23	4	1

Table 10. Provider Productivity and Efficiency Results[a,b]

		Restricted	Unrestricted	*P* value
Productivity	n	**1669**	**1687**	
Orders placed, no.		12.1 (5.2–28.1)	12.2 (5.0–28.2)	.95
Patients with orders placed, no.		4.3 (2.3–7.2)	4.2 (2.3–7.2)	.79
Efficiency	n	**1348**	**1354**	
Time on system, min.		98.5 (29.9–189.0)	97.9 (31.5–191.3)	.42
Screen switches, no.		183 (57–385)	179 (59–388)	.91
Mouse clicks, no.		671 (211–1349)	643 (215–1350)	.52
Key presses, no.		2784 (338–7162)	2959 (411–7455)	<.0005
Computer log ins, no.		6.0 (2–11)	6.0 (2–11)	.84

[a] Median (interquartile range) per provider per day. *P* values calculated using Mann-Whitney U-test.
[b] Data collected for 2-month period, September 23, 2016 to November 28, 2016.

ADDENDUM: SURVEY OF PROVIDERS IN THE RANDOMIZED TRIAL

Provider Survey: Methods

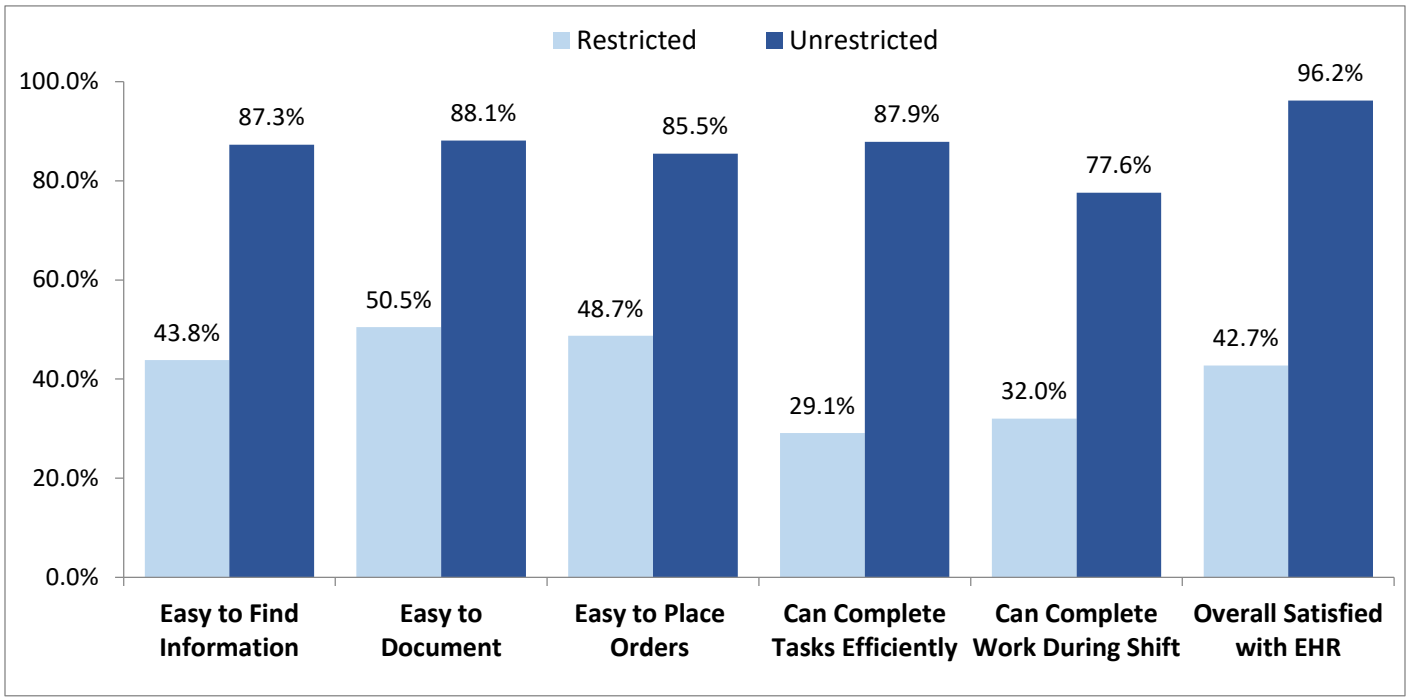
We conducted a survey of all healthcare providers included in the randomized comparative effectiveness trial to further inform decision-making regarding the maximum number of patient records to allow open in EHRs. The purpose of the survey was to elicit 1) feedback about their experience during the study, and 2) their opinions about safety and efficiency related to the maximum number of patient records allowed open in the configuration to which they were assigned. To gain an understanding of variations among types of providers and the settings in which they work, we merged the survey data with the outcomes data to correlate provider practice patterns with their attitudes about safety and efficiency.

The survey was conducted before the conclusion of data collection for the randomized trial. The survey was created and distributed by email using REDCap, which is a secure web-based, password-protected survey and data management platform. All ordering providers randomized during the trial period were eligible to complete the survey. Research personnel generated a list of email addresses for eligible providers and uploaded the list into the survey system. An email was sent via REDCap to the providers with a brief explanation of the study and a link to the electronic survey. The first page of the survey was an electronic information sheet, which served as consent for participation in the survey, and included the survey purpose, contact information, as well as risks and benefits of participation. Providers were assured that their participation was voluntary and their responses would be kept confidential. Once data collection was completed, the study statistician downloaded the survey data, merged it with the randomized trial data, and replaced the actual identifiers with pseudo-identifiers. Survey items were analyzed using descriptive statistics.

Provider Survey: Preliminary Results

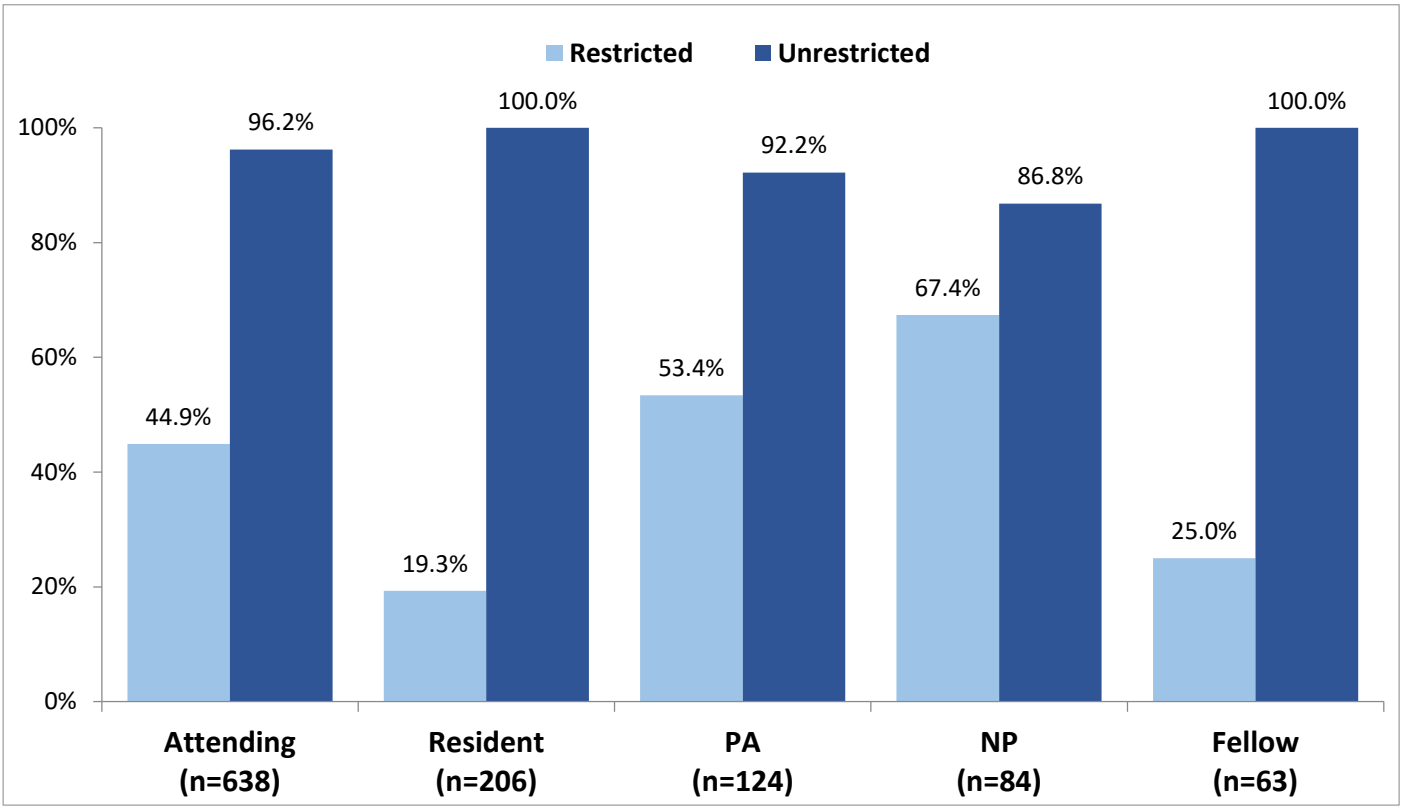
Of 3356 providers included in the randomized trial, 1236 responded to the survey for a response rate of 37%. Respondents were evenly distributed across trial arms, with 634 respondents in the Restricted arm and 602 in the Unrestricted arm. Overall, a significantly greater proportion of providers in the Unrestricted arm reported ease of use and overall satisfaction with their EHR configuration compared with providers in the Restricted arm ($P < .001$ for all comparisons) (**Figure 3**). Results were consistent when stratified by provider type (**Figure 4**), practice setting, and volume of orders placed. Further analysis is underway.

Figure 3. Usability and Satisfaction with EHR by Randomization Arm



$P < .001$ all comparisons.

Figure 4. Overall Satisfaction with EHR by Provider Type



P < .001 all comparisons. PA, physician assistant; NP, nurse practitioner.

References

1. Adelman JS, Kalkut GE, Schechter CB, et al. Understanding and preventing wrong-patient electronic orders: a randomized controlled trial. J Am Med Inform Assoc 2013 Mar-Apr;20(2):305-310.
2. National Quality Forum. Patient Safety 2015: Draft Report for Comment. 2015. http://www.qualityforum.org/Projects/n-r/Patient_Safety_Measures_2015/Draft_Report_for_Comment.aspx. Accessed February 24, 2017.
3. National Quality Forum. Patient Safety 2015: Final Technical Report. 2016. http://www.qualityforum.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=81724. Accessed February 15, 2017.
4. Kannampallil TG, Manning JD, Chestek DW, et al. Effect of number of open charts on intercepted wrong-patient medication orders in an emergency department. J Am Med Inform Assoc 2017 Sep 11;25(6):739-743.
5. Green RA, Hripcsak G, Salmasian H, et al. Intercepting wrong-patient orders in a computerized provider order entry system. Ann Emerg Med 2015 Jun;65(6):679-686.
6. Sharek PJ, Horbar JD, Mason W, et al. Adverse events in the neonatal intensive care unit: development, testing, and findings of an NICU-focused trigger tool to identify harm in North American NICUs. Pediatrics 2006 Oct;118(4):1332-1340.
7. Levinson DR. Adverse Events in Hospitals: Methods for Identifying Events. 2010. https://oig.hhs.gov/oei/reports/oei-06-08-00221.pdf. Accessed May 30, 2017.
8. Classen DC, Resar R, Griffin F, et al. 'Global trigger tool' shows that adverse events in hospitals may be ten times greater than previously measured. Health Aff (Millwood) 2011 Apr;30(4):581-589.
9. Joint Commission. 2018 Hospital National Patient Safety Goals. 2018. https://www.jointcommission.org/assets/1/6/2018_HAP_NPSG_goals_final.pdf. Accessed October 11, 2018.
10. Hyman D, Laire M, Redmond D, Kaplan DW. The use of patient pictures and verification screens to reduce computerized provider order entry errors. Pediatrics 2012 Jul;130(1):e211-219.
11. Office of the National Coordinator for Health Information Technology. Patient Identification SAFER Guide 2014. https://www.healthit.gov/sites/default/files/safer/guides/safer_patient_identification.pdf. Accessed December 9, 2018.
12. Joint Commission. Safe use of health information technology. *Sentinel Event Alert, Issue 54* 2015. http://www.jointcommission.org/assets/1/18/SEA_54.pdf. Accessed July 27, 2018.
13. Lowry SZ, Quinn MT, Ramaiah M, et al. Technical evaluation, testing, and validation of the usability of electronic health records. 2012. https://www.healthit.gov/sites/default/files/safer/guides/safer_patient_identification.pdf. Accessed June 18, 2018.
14. Paparella SF, 10.1016/j.jen.2012.03.009. Accurate patient identification in the emergency department: Meeting the safety challenges. Journal of Emergency Nursing 2012;38(4):364-367.
15. Levin HI, Levin JE, Docimo SG. "I meant that med for Baylee not Bailey!": a mixed method study to identify incidence and risk factors for CPOE patient misidentification. AMIA Annu Symp Proc 2012;2012:1294-1301.
16. Galanter W, Falck S, Burns M, Laragh M, Lambert BL. Indication-based prescribing prevents wrong-patient medication errors in computerized provider order entry (CPOE). J Am Med Inform Assoc 2013 May 1;20(3):477-481.
17. Adelman JS, Berger MA, Rai A, et al. A national survey assessing the number of records allowed open in electronic health records at hospitals and ambulatory sites. J Am Med Inform Assoc 2017 Sep 1;24(5):992-995.
18. Aspden P, Corrigan JM, Wolcott J, Erickson SM, eds. *Patient Safety: Achieving a New Standard for Care.* Washington (DC): National Academies Press (US); 2004.
19. Quality Interagency Coordination Task Force. Doing What Counts for Patient Safety: Federal Actions to Reduce Medical Errors and their Impact. 2000. https://archive.ahrq.gov/quic/Report/errors6.pdf. Accessed July 27, 2018.
20. Leape L, Abookire S. WHO Draft Guidelines for Adverse Event Reporting and Learning Systems: From Information to Action. 2005. http://apps.who.int/iris/bitstream/handle/10665/69797/WHO-EIP-SPO-QPS-05.3-eng.pdf?sequence=1&isAllowed=y. Accessed July 27, 2018.

21. Institute for Healthcare Improvement. Create a Reporting System. 2017. http://www.ihi.org/resources/Pages/Changes/CreateaReportingSystem.aspx. Accessed July 27, 2018.
22. Wu AW, ed *The Value of Close Calls in Improving Patient Safety: Learning how to Avoid and Mitigate Patient Harm.* Oakbrook Terrace, IL: Joint Commission Resources; 2011.
23. Ash JS, Berg M, Coiera E. Some unintended consequences of information technology in health care: the nature of patient care information system-related errors. J Am Med Inform Assoc 2004 Mar-Apr;11(2):104-112.
24. Camargo CA, Tsai CL, Sullivan AF, et al. Safety climate and medical errors in 62 US emergency departments. Ann Emerg Med 2012 Nov;60(5):555-563.
25. Epstein SK, Huckins DS, Liu SW, et al. Emergency department crowding and risk of preventable medical errors. Intern Emerg Med 2012 Apr;7(2):173-180.
26. Magid DJ, Sullivan AF, Cleary PD, et al. The safety of emergency care systems: Results of a survey of clinicians in 65 US emergency departments. Ann Emerg Med 2009 Jun;53(6):715-723.
27. Smits M, Groenewegen PP, Timmermans DR, van der Wal G, Wagner C. The nature and causes of unintended events reported at ten emergency departments. BMC Emerg Med 2009 Sep 18;9:16.
28. Walter SR, Li L, Dunsmuir WTM, Westbrook JI. Managing competing demands through task-switching and multitasking: a multi-setting observational study of 200 clinicians over 1000 hours. BMJ Quality & Safety 2014;23(3):231-241.
29. Ratwani RM, Fong A, Puthumana JS, Hettinger AZ. Emergency Physician Use of Cognitive Strategies to Manage Interruptions. Ann Emerg Med 2017 Nov;70(5):683-687.
30. Westbrook JI, Raban MZ, Walter SR, Douglas H. Task errors by emergency physicians are associated with interruptions, multitasking, fatigue and working memory capacity: a prospective, direct observation study. BMJ Qual Saf 2018 Aug;27(8):655-663.
31. Chisholm CD, Dornfeld AM, Nelson DR, Cordell WH. Work interrupted: a comparison of workplace interruptions in emergency departments and primary care offices. Ann Emerg Med 2001 Aug;38(2):146-151.
32. Westbrook JI, Coiera E, Dunsmuir WT, et al. The impact of interruptions on clinical task completion. Qual Saf Health Care 2010 Aug;19(4):284-289.
33. Westbrook JI. Interruptions and multi-tasking: moving the research agenda in new directions. BMJ Qual Saf 2014 Nov;23(11):877-879.
34. Office of the National Coordinator for Health Information Technology. Percent of Hospitals, By Type, that Possess Certified Health IT. Health IT Quick-Stat #52. dashboard.healthit.gov/quickstats/pages/certified-electronic-health-record-technology-in-hospitals.php. 2018. Accessed December 12, 2018.
35. Office of the National Coordinator for Health Information Technology. Office-based Physician Electronic Health Record Adoption. Health IT Quick-Stat #50. dashboard.healthit.gov/quickstats/pages/physician-ehr-adoption-trends.php. 2016. Accessed December 12, 2018.
36. Bureau of Labor Statistics. U.S. Department of Labor. Occupational Outlook Handbook. https://www.bls.gov/ooh/healthcare/physician-assistants.htm. 2016. Accessed December 12, 2018.