Final Progress Report to Agency for Healthcare Research and Quality

Title of Project
Providing Evidence and Developing a Toolkit to Accelerate the Adoption of Patient Photographs in Electronic Health Records

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1. STRUCTURED ABSTRACT

Purpose: To test the effectiveness of patient photos for preventing wrong-patient order errors in two electronic health record (EHR) systems.

Scope: Wrong-patient errors remain a threat to patient safety, requiring evidence-based interventions.

Methods: We conducted two multisite randomized controlled trials (RCTs): 2-arm design in Allscripts, ID Alert with vs without photo (control); 4-arm design in Epic, 1) No photo (control), 2) Storyboard with photo, 3) Alert with photo, 4) both Storyboard and Alert with photo. Ordering clinicians were randomized in a 1:1 ratio to study groups. Using the Wrong-Patient (WP) Retract-and-Reorder measure, the outcome was WP order sessions, defined as series of orders placed by 1 clinician for 1 patient that included ≥1 WP order. Mixed-effects logistic regression models estimated the effect of intervention arm(s) vs control, reported as OR (SE) and *P* value.

Results: 2-arm RCT results are pending. The 4-arm RCT included 8,768 clinicians, 1,297,070 patients, 15,942,190 order sessions, and 23,300 WP order sessions. Characteristics were balanced across arms. Planned ITT analysis versus control: Arm 2 OR 0.90 (0.04), *P*<.05; Arm 3 OR 0.87 (0.04), *P*<.01; Arm 4 OR 0.84 (0.04), *P*<.001. As only 63.4% of order sessions were placed with a photo available, we conducted a 2×4 stratified analysis by presence/absence of photo. In the stratum with photos: OR 0.85 (0.04), *P*<.01; OR 0.87 (0.04), *P*<.01; OR 0.81 (0.04), *P*<.0001, respectively, versus photo control. Photo interventions significantly decreased WP orders versus control; between-group differences were not statistically significant.

Keywords: computerized provider order entry, patient photo, wrong-patient errors.

2. PURPOSE

The purpose of this study was to determine the effectiveness of displaying patient photos in the EHR for preventing wrong-patient order errors. We conducted two randomized controlled trials (RCTs) in two different EHR systems, Allscripts and Epic, each with different photo functionality and photo configurations. The two RCTs were designed to assess the magnitude of effect of displaying patient photos in a passive intervention (i.e., photo in banner, called “Storyboard” in Epic) and in an interruptive intervention (i.e., photo in an ID Verification Alert), alone and in combination, on reducing wrong-patient orders. The 2-arm Allscripts RCT tested an interruptive alert with versus without a photo (control). The 4-arm Epic RCT tested three interventions versus no photo (control): Storyboard with photo; Alert with photo; both Storyboard and Alert with photo. Conducting studies in two different EHRs provides evidence of generalizability and informs the optimal configuration of patient photos in the EHR. Taking into consideration clinician alert fatigue, the study aimed to quantify the benefit of the interruptive alert relative to the passive intervention to ensure that benefits of the alert would outweigh the potential burden on clinicians. The study proposed the following specific aims.

Aim 1: Provide **rigorous evidence** for the efficacy of displaying patient photographs in EHRs by conducting a multisite, cluster randomized controlled trial comparing the frequency of wrong-patient orders among clinicians randomized to view order screens ***with*** versus ***without*** patient photographs.

Aim 1A: Conduct subgroup analyses to identify factors that impact effectiveness of patient photographs on the frequency of wrong-patient orders, including characteristics of clinicians, patients, and order sessions.

Aim 2: Demonstrate **generalizability** by conducting multiple before-after implementation studies using different EHR systems to evaluate the effectiveness of patient photographs for reducing the frequency of wrong-patient orders across sites and EHR systems.

Aim 3: Provide **implementation guidance** for displaying patient photographs in EHRs by developing the first AHRQ Health IT Toolkit, “Implementing Patient Photographs in EHR Systems.”

Aim 3A: Conduct a qualitative evaluation to examine user perceptions and experience of patient photographs in the different EHR systems, including staff, clinicians, and patients.

Note: For Aim 2, we planned to conduct before-after studies, as we did not expect it to be technically feasible to randomize clinicians to study arms in other EHRs. However, we were able to configure Epic to randomize clinicians in a 1:1:1:1 ratio into one of four study groups (see **4. Methods**).

3. SCOPE (Background, Context, Settings, Participants, Incidence, Prevalence).

Background

The problem of wrong-patient orders. Although computerized provider order entry (CPOE) systems are associated with a reduction in medical errors,[1-4] when orders are placed electronically certain types of errors, including placing orders on the wrong patient, may occur more frequently.[5-8] The hazard of wrong-patient electronic orders was highlighted by one hospital's report of over 5,000 wrong-patient orders in 1 year.[9] All types of orders can be placed on the wrong patient including medications, lab and imaging tests, procedures, nursing orders, consults, and discharge orders. If an order is carried out on the wrong patient, it may lead to serious patient harm.

ID Verification Alerts to prevent wrong-patient orders. Prior research using the Wrong-Patient Retract-and-Reorder (WP-RAR) measure showed that ID verification alerts significantly reduced wrong-patient orders. Adelman et al conducted a 3-arm RCT in a large healthcare system to assess the effectiveness of two alerts: an ID-verify alert that displayed the patient's identifiers when initiating orders, requiring a single click to proceed; and an ID-reentry alert, requiring the clinician to enter the patient's initials, gender, and age to proceed. Compared with control (no alert), the ID-verify alert significantly reduced wrong-patient orders by 16% (OR 0.84, 95% CI 0.72–0.98) and the ID-reentry alert by 41% (OR 0.60, 95% CI 0.50–0.71).[9] Citing these results, the Office of the National Coordinator for Health Information Technology (ONC) *Patient Identification SAFER Guide* recommends verifying patient identification at the time of ordering as a best practice.[10] The 2-arm study in Allscripts aimed to determine the added effect of a patient photo displayed in the alert versus the alert with no photo for reducing wrong-patient orders.

How patient photographs displayed in EHRs can prevent wrong-patient electronic orders. Prior research has shown that cognitively processing a photograph (face recognition) requires significantly less effort than reading a patient's name.[11] As such, displaying a patient photograph has the potential to be a fast and accurate method for verifying a patient's identity when placing electronic orders. Limited evidence suggests that patient photographs may be a promising strategy for reducing wrong-patient orders.[12,13] In a study conducted by Hyman et al (2012), wrong-patient orders reported to a voluntary incident reporting system declined from 12 to 3 from the year pre- versus post-implementation of patient photos in the EHR.[12] This study was limited by small sample size, before-after design, and reliance on voluntary reporting of errors. In a retrospective cohort study conducted by Salmasian et al (2020),[13] orders placed in the presence of a patient photo significantly reduced the risk of wrong-patient order errors (unadjusted OR, 0.72; 95% CI, 0.57–0.89; adjusted OR, 0.57; 95% CI, 0.52–0.61) in the emergency departments of a large academic medical center. However, the percentage of orders placed with a photo present reached only 46% by the end of the study period. Displaying patient photographs in EHRs is recommended by ONC's *Patient Identification SAFER Guide*.[10] However, adoption of health information technology safety recommendations has been limited.[14] We hypothesize that large RCTs using an automated and reliable measure of wrong-patient errors will demonstrate that patient photographs significantly reduce wrong-patient orders.

Wrong-Patient Retract-and-Reorder Measure for identifying wrong-patient errors. The WP-RAR measure is a validated, reliable, and automated method for identifying wrong-patient orders.[9,15] The WP-RAR measure identifies orders that are placed for a patient and retracted within 10 minutes, then reordered by the same clinician for a different patient within the next 10 minutes. These are near-miss errors, self-caught by the clinician before they reach the patient and cause harm. In one study, the WP-RAR measure identified more than 5,000 wrong-patient orders in 1 year, with a rate of 58 wrong-patient orders per 100,000 orders.[9] Real-time telephone interviews with clinicians who placed and retracted the orders determined that the WP-RAR measure correctly identified errors in 170 of 223 cases (positive predictive value 76.2%). The WP-RAR measure has been used as the primary outcome measure in RCTs and quasi-experimental studies to evaluate interventions to reduce wrong-patient errors, and in several observational studies to examine the epidemiology of wrong-patient orders in a range of clinical settings and patient populations.[9,13,16-22] The measure was used in an RCT comparing the effect of two EHR configurations on the risk of wrong-patient order errors, funded by AHRQ and published in *JAMA* in 2019.Thus, the WP-RAR measure provides reliable and robust outcome data for this study.[16]

Why are near-miss errors important in patient safety research? The WP-RAR measure captures near-miss wrong-patient errors, caught and corrected by the ordering clinician before they reach the patient. The use of near-miss errors to test safety improvements in healthcare is encouraged by every major organization

dedicated to patient safety including the Agency for Healthcare Research and Quality, Institute of Medicine/ National Academy of Medicine, World Health Organization, Institute for Healthcare Improvement, and The Joint Commission, because near-miss errors are posited to share the same pathway as errors that reach the patient and cause harm.[23-28]

Context

Use of patient photos in EHRs. In 2013, Adelman et al conducted a national survey of hospitals to assess the use of patient photos in EHRs (unpublished data). More than 80% of 131 responding hospitals reported using EHRs with the capability to display patient photos, but only 17.6% used this function at that time. Although current adoption of patient photos is unknown, establishing the effectiveness of patient photos for preventing wrong-patient errors provides hospitals with needed evidence to overcome barriers and adopt this safety practice. Several barriers to implementation of patient photos in healthcare systems have been identified, including privacy concerns, high patient acuity, costs, changes to registration workflow, time pressures, and technical issues.[12,13] Patient refusal, however, has not been shown to be a major barrier to obtaining photos during the registration process. In a study conducted at Columbia University Irving Medical Center, all 172 patients observed at registration in an emergency department and an outpatient clinic patients agreed to have their photo taken and uploaded into the EHR.[29] As the barriers to implementation are predominantly organizational and operational health system issues, there is great potential to successfully scale the adoption of patient photos with the application of targeted strategies.

Availability of patient photos. The availability of patient photos in the EHR is key to the effectiveness of our interventions based on the presence of a photo when placing electronic orders. We found that 3 months after the start of the study the percentage of patients with photos in the EHR at the participating study sites was 30%–40%, consistent with rates reported in other studies.[13,30] Over the course of 3 months, the research team worked with Patient Services, Information Services, and Operations to identify and address barriers to increasing patient photo uptake (described in detail below in **Aim 3**). Solutions targeted the needs of each stakeholder:

***Patient Services*:** developing a job aid and training on how to take photos and when to delete/replace photos; deploying cameras; developing and disseminating patient education materials in registration areas; providing written scripts; holding a competition for admissions staff.

***Information Systems**:* activating settings on kiosks to enable patients to take their own photo during registration; sending messages to patients through the patient portal to upload a photo; migrating patient photos from the previous EHR system; developing patient photo performance reports to share with Patient Services.

Operations: clarifying policy that patients may remove masks briefly to take a photo for identification purposes.

These targeted strategies resulted in a sharp and sustained increase in the availability of photos in the EHR at study sites (**Figure 1**). In the first 3 months versus last 3 months of the study period, there was a significant

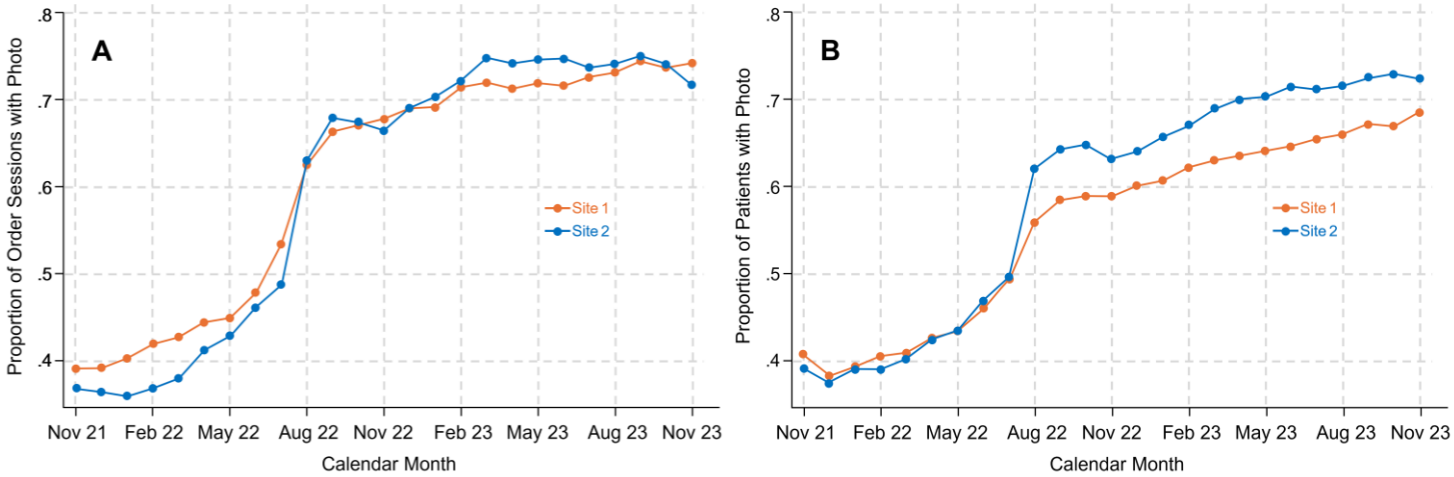


Figure 1. Photo availability in the EHR over time. **A**) Proportion of order sessions with a photo available; **B)** Proportion of patients with a photo available. The order session is the unit of analysis for the study, defined as a series of orders placed by 1 clinician for 1 patient.

increase in the overall proportion of order sessions (39.1% to 74.1%, *P*<.0005) and patients (35.6% to 65.5%, *P*<.0005) with a photo available at the time the order was placed. These results were consistent across all subgroups by age, gender, race, ethnicity, and insurance status.

Settings
Study sites included Columbia University Irving Medical Center (CUIMC), Weill Cornell Medicine, Johns Hopkins Medicine, Albert Einstein College of Medicine (for data analysis only), and Brigham & Women's Hospital (for consultation only). The studies were conducted in two leading EHR systems, Allscripts and Epic. For the study in Allscripts, two NewYork-Presbyterian (NYP)/CUIMC facilities that utilized Allscripts EHR were included: Milstein Hospital and Allen Hospital. Because all NYP facilities transitioned to Epic by December 2021, we evaluated the effectiveness of patient photographs in Epic at the following facilities: 4 at CUIMC (Milstein Hospital, Allen Hospital, Morgan Stanley Children's Hospital, Westchester Hospital), and 3 at Weill Cornell Medicine (Weill Cornell Medical Center, Lower Manhattan Hospital, Westchester Behavioral Health Center). Data analysis was conducted at Albert Einstein College of Medicine by study biostatistician, Dr. Clyde Schechter. Dr. Hojjat Salmasian at Brigham & Women's Hospital served as consultant and technical advisor.

Johns Hopkins University sites were not included in data collection and analysis, as organizational and institutional issues impeded the full implementation of the required Epic build and the ability to conduct of the study per the planned design. Although no data were collected at Johns Hopkins, the Johns Hopkins site PI, Dr. Allen Chen, MD, PhD, MHS, has been instrumental in his guidance with his extensive knowledge of Epic functionality, health services research methods, data analysis, and health informatics interventions.

The study protocol was approved by the Institutional Review Boards of all participating sites. Informed consent was waived for clinicians and patients.

Participants
Clinicians. All clinicians with the authority to place electronic orders (e.g., attendings, residents, fellows, physician assistants, nurse practitioners) at participating sites were eligible for inclusion in the study.
Patients. Since all patients are at risk for an order error, all patients for whom at least 1 order was placed by a randomized clinician during the study period were included in the analysis.

Incidence/Prevalence
In prior studies using the WP-RAR, the rate of wrong-patient order errors in large academic medical centers ranged from 50 to 76 per 100,000 orders or 89 to 150 per 100,000 order sessions overall,[9,16] with higher rates in high-risk settings such as the emergency department (163 per 100,000 orders)[19] and neonatal intensive care units (117 per 100,000 orders).[18]

4. METHODS

Study Design
This study consisted of two randomized controlled trials (RCTs) to assess the effectiveness of patient photos displayed in the EHR for reducing wrong-patient orders: a 2-arm design in Allscripts; and a 4-arm design in Epic to generalize study findings in a different EHR system and to test the effect of different configurations.

Aim 1: 2-Arm Randomized Controlled Trial in Allscripts. For Aim 1, *to provide rigorous evidence for the efficacy of displaying patient photographs in the electronic health record (EHR)*, we conducted a 2-arm cluster randomized trial in Allscripts EHR at two hospitals at Columbia University Irving Medical Center (CUIMC)/NewYork-Presbyterian (NYP). All clinicians with the authority to place electronic orders were pseudo-randomized to study arm based on a specific digit in their internal user ID in Allscripts (which clinicians were not aware of or have access to). Clinicians were randomized in a 1:1 ratio to one of two study groups:

1. **Photo in Identification Alert:** For all orders, an Alert displayed with patient information and a patient photo (when the patient had a photo available in the system).
2. **No Photo in Identification Alert**: For all orders, an Alert displayed with patient information and an icon indicating the patient's sex.

The 2-arm RCT design is shown in **Figure 2**. The functionality to display the Alert with patient identifiers before placing orders, the photo display within the alert, and the randomization of ordering clinicians in Allscripts were designed and built by informatics experts at CUIMC/NYP.

The study period for the Allscripts 2-arm RCT was 2/1/2017 to 1/31/2020. Data have been extracted from the health system data warehouse and analysis is underway. Therefore, the remainder of this report focuses on Aim 2, the design, methods, and results of the 4-arm RCT in Epic, and Aim 3. When the analysis is complete, this report will be replaced to reflect the methods and results of both RCTs.

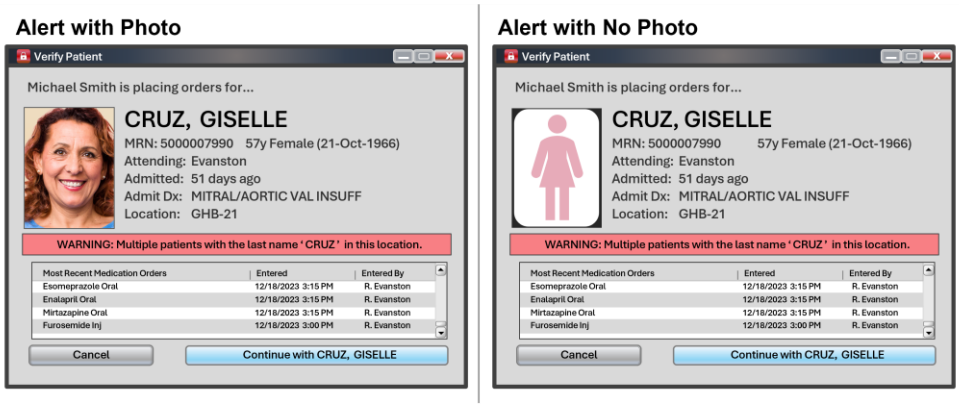


Figure 2. 2-Arm Randomized Controlled Trial in Allscripts. (Not a real patient)

Aim 2: 4-Arm Randomized Controlled Trial in Epic. For Aim 2, *to demonstrate generalizability by conducting studies using different EHR systems*, we planned to conduct before-after studies, as we did not expect it to be technically feasible to randomize clinicians to study arms in other EHRs. However, we worked closely with Epic to configure four study arms and randomize ordering clinicians in a 1:1:1:1 ratio to one of the four arms. This design enables assessment of configurations of patient photos that are applicable to other EHRs, some of which display patient photos in the banner, in identification alerts, or both.

Epic Photo Display Functionality. We used existing functionality for displaying patient photos in Epic. There are two main features that display patient photos to help ensure accurate patient identification, **Storyboard** and **Identification Alerts**. **Figure 3** shows how these features appear in Epic, with and without patient photos available.

A. **Storyboard**, a panel along the left side of the screen that displays patient identifiers and a patient photo if available. If no photo is available, the patient's initials are displayed. This is the default for Storyboard in Epic. Storyboard appears on most screens in the EHR, including when placing orders. Storyboard is a passive intervention, displaying patient information but requiring no action by the user.
B. **Identification Alert**, an interruptive "popup" alert that displays patient identifiers and a photo if available. If no photo is available, the Alert appears without a photo. The is the default in Epic if the Alert is enabled. The alert fires immediately before the ordering clinician places the order, requiring a single click to Accept or Cancel the order.
C. We use **Schematic** representations to graphically depict the study arms, as they appear with and without photos available, to describe the analyses and results throughout this report.

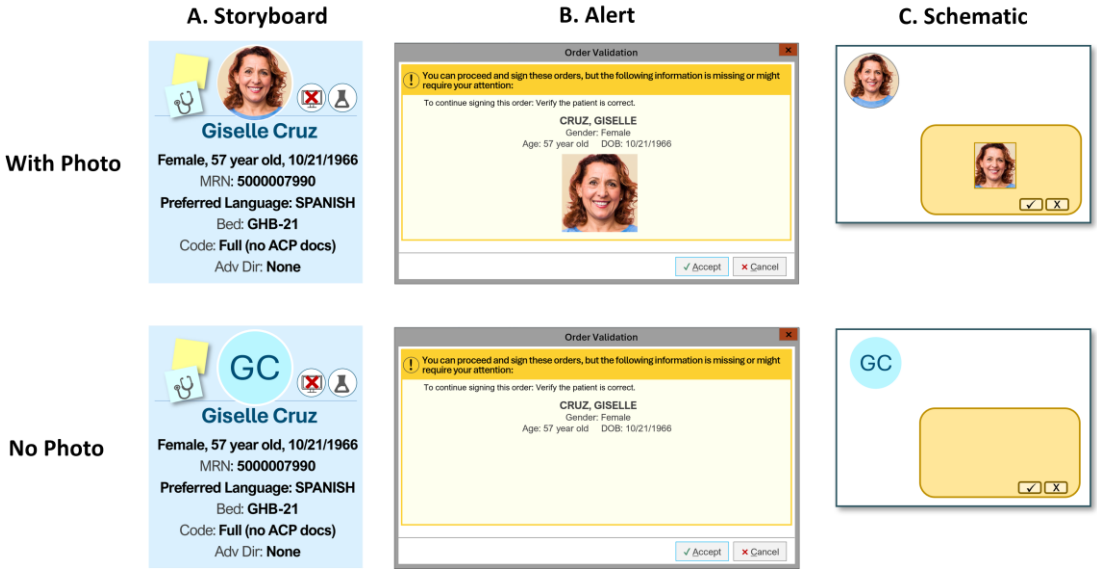


Figure 3. Photo Display in Epic, with and without patient photos available.

Study Interventions. Two main patient photo display features were used to create the 4 study conditions as shown in **Figure 4**. For this study, Epic built functionality that suppressed patient photos based on study arm.

Arm 1. No Photo in Storyboard/No Alert (Control): No patient photo displayed in Storyboard, no Alert displayed.
Arm 2. Photo in Storyboard/No Alert: Patient photo displayed in Storyboard (if photo available), no Alert displayed.
Arm 3. No Photo in Storyboard/Alert with Photo: No patient photo in Storyboard, Alert displayed with a patient photo (if photo available).
Arm 4. Photo in Storyboard Plus Alert with Photo: Patient photo in Storyboard and Alert displayed with a patient photo (if photo available).

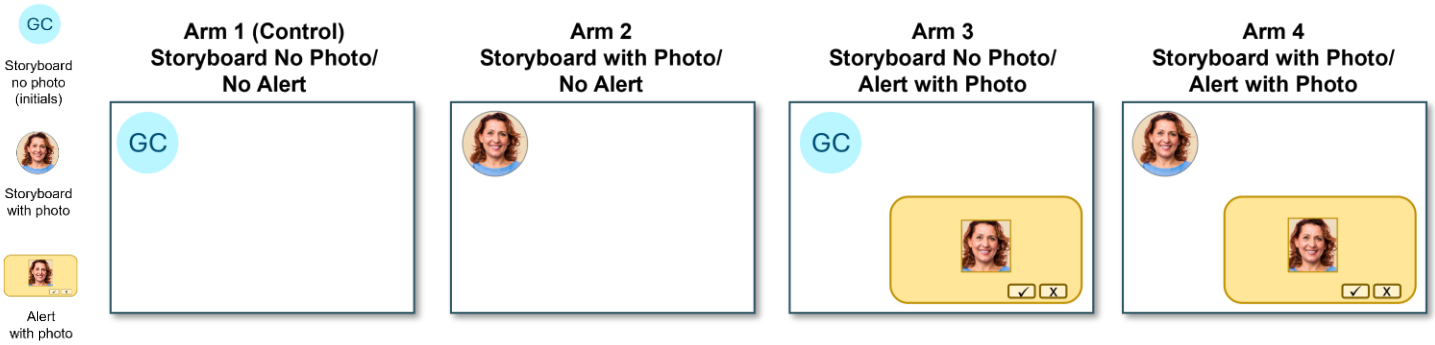


Figure 4. Planned 4-Arm Randomized Controlled Trial in Epic.

Non-Study Interventions and Potential Contamination. In addition, before the start of the study Epic launched new features that displayed patient photos to help clinicians select the right patient. At the study sites, these features included the Patient List, Patient Search, Secure Chat, and Outpatient Scheduling. The new features were not part of the original study design and not part of the build in Epic that enabled suppression of patient photos based on study arm. These non-study interventions may have introduced contamination bias as they could be viewed by clinicians in all four arms of the study, including the control arm.

Measures. The unit of analysis was the order session, defined as a series of orders placed consecutively by a single provider for a single patient. If a clinician places orders in the wrong patient's record, several orders may be placed and then subsequently retracted together. Orders are clustered within order sessions; thus, the order session, rather than each order, represents an independent opportunity for a wrong-patient error to occur. The primary outcome was wrong-patient order sessions, defined as order sessions that contained at least 1 wrong-patient order. The primary outcome was identified using the WP-RAR measure, a validated, reliable, and automated measure endorsed by the National Quality Forum.[9,15] The WP-RAR measure is an electronic query run retrospectively against every eligible order placed during the study period to identify near-miss wrong-patient orders (see **Scope, Background** above).

Randomization. New and existing functionality in Epic was configured to assign ordering clinicians to one of the four arms in a 1:1:1:1 ratio using Epic Groupers. Research personnel, with the support of IT personnel, created and tested the study groupers and the photo display functionality for the four arms in Epic at all study sites. Ordering clinicians from each of the study sites were randomized by the CU biostatistician and assignments were uploaded into the groupers by IT personnel at two time points: at the beginning of the study period (11/16/2021); and at 1 year after the start of the study (11/7/2022).

Data Sources/Collection. All orders placed at study sites during the study period 11/17/2021 to 11/16/2023 were extracted from the healthcare system data warehouse. Only orders placed by randomized clinicians during the study period were included in the dataset for analysis; therefore, clinicians who did not place at least 1 order during the study period were not included in the final data. The data were deidentified by the CU programmer and transferred to Dr. Clyde Schechter for analysis. The data files were then imported into Stata version 18MP for Windows (StataCorp., College Station, TX) for analysis.

Data Analysis. Descriptive Statistics: The data design had two levels, the order session level and the ordering clinician level, with sessions nested within clinicians. As randomization occurred at the clinician level, counts and percentages of attributes of order sessions were calculated and disaggregated by study arm to ensure balance on relevant factors across randomization groups. The following variables were collected for all

orders: role of ordering clinician (attending, resident, physician assistant, nurse practitioner, other); medical center (CU, WC); hospital site; clinical setting (inpatient, emergency department, outpatient); patient age, gender, race, ethnicity, insurance status; photo available (yes, no); order date/time; order retraction date/time. From order date and time, we extracted the hour of the day, day of the week, and quarter of the year. In addition, counts and percentages were calculated to describe characteristics of clinicians (clinician level), patients (patient level), and order sessions disaggregated by the presence/absence of patient photos.

Statistical Analysis: The raw incidence rates of WP order sessions were calculated overall and by randomization group. The primary outcome variable was dichotomous, indicating whether each order session contained a wrong-patient order, and reported as the number of wrong-patient order sessions per 100,000 order sessions. Consistent with the planned 4-arm design, we carried out an intention-to-treat (ITT) analysis using mixed-effects logistic regression, with order sessions as the units of analysis, WP order session as the outcome variable, study group as the independent variable, and a random intercept at the clinician level. **Figure 5A** depicts the 4 study arms and planned ITT analysis. The top row (Yes) shows the intended design if there was a photo available in the intervention Arms 2, 3, and 4 at the time every order was placed. However, because not every patient had a photo in the EHR, there was a mix of orders placed with and without a photo present. The bottom row (No) shows the display in the intervention arms if no photo was available when the order was placed. Arms 1 and 2 are identical; and Arms 3 and 4 are identical, introducing an unintended condition of the Alert displayed with no photo. Thus, in the 4-arm analysis, each arm included order sessions placed with and without a photo present. To account for the suboptimal percentage of order sessions with photos (62.4%), and potential contamination by photos displayed in non-study interventions, we conducted additional primary (**Figure 5B**) and secondary analyses (**5C–5D)**. For all analyses, the effect was estimated using odds ratio (OR), standard error (SE), and Wald test of significance with 2-sided alpha=.05.

Primary Analyses
Intention-to-Treat (ITT) analysis: estimating the effect of intervention Arms 2, 3, and 4 versus control Arm 1, regardless of whether there was a patient photo available (**Figure 5A**).

2×4 Stratified analysis by presence/absence of photo: within the Photo stratum, estimating the effect of intervention Arm 2Y, 3Y, and 4Y versus control Arm 1Y with photo available; and within the No Photo stratum, comparing the effect of Arm 2N, 3N, and 4N versus control Arm 1N with no photo available (**Figure 5B**).

Secondary Analyses
Photo Intervention versus No-Photo Control: estimating the effect of intervention arms 2Y, 3Y, and 4Y versus the control Arm 1N with no photo available (**Figure 5C**).

Photo vs No Photo within Each Arm: estimating the effect of photo available versus no photo available within each randomized Arm 1Y vs 1N, 2Y vs 2N, 3Y vs 3N, and 4Y vs 4N, i.e., “No Photo” is the control condition within each Arm (**Figure 5D**).

Power Analysis. The power analysis for the 4-Arm study was based on the following assumptions: 8,268 clinicians, randomized in 1:1:1:1 ratio to study arms, generating an average of 74 order sessions per month, with data collected for 1 year, for a total of 7,341,984 order sessions. This yielded 91% power (95% CI 88%–94%) to detect an OR of 0.75 (i.e., 25% reduction in wrong-patient orders) for either photo intervention (Storyboard or Alert) compared with control. Power to detect an additional 15% reduction by the combination of photo interventions (Storyboard and Alert) compared to either alone was 99.8% (95% CI 98.6%–99.9%).

Limitations. First, no photo was available for 38% of order sessions included in the analysis. In addition, patient photos were displayed in non-intervention features of the EHR during the study period. As a result of this noncompliance and potential contamination bias, the effectiveness of the interventions may have been underestimated. However, the stratified analysis accounts for these biases and estimates the effect of the interventions as intended. Second, the WP-RAR measure detects only near-miss wrong-patient orders, caught and corrected before reaching the patient. Other types of unmeasured wrong-patient errors may have been prevented by the intervention. However, the WP-RAR measure has been used in several RCTs, and the use of near-miss errors to test safety interventions is endorsed by major organizations dedicated to patient safety.[25,28,31-33]

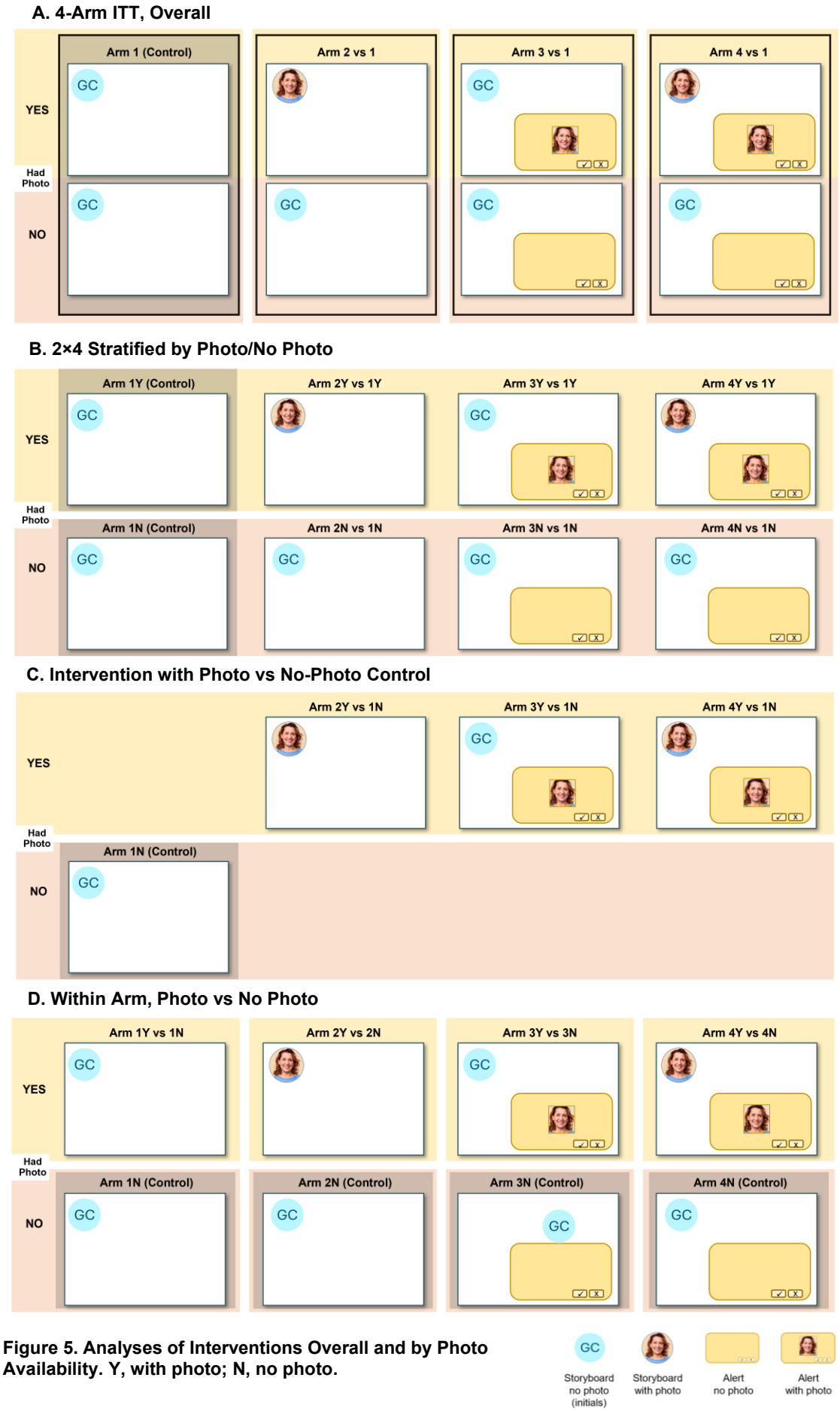


Figure 5. Analyses of Interventions Overall and by Photo Availability. Y, with photo; N, no photo.

Results

Principal Findings. The 4-arm RCT included 8,768 clinicians, 1,297,070 patients, 57,452,163 orders in 15,942,190 order sessions. **Table 1** shows characteristics of clinicians (the unit of randomization) and order sessions disaggregated by study arm. All characteristics were balanced across randomized groups.

Table 1. Characteristics of Clinicians and Order Sessions

Characteristic	Arm 1 (Control) Storyboard no Photo/No Alert	Arm 2 Storyboard w Photo/No Alert	Arm 3 Storyboard no Photo/Alert w Photo	Arm 4 Storyboard w Photo/ Alert w Photo
Clinicians (N=8768)*	2,199 (25.1)	2,202 (25.1)	2,171 (24.8)	2,196 (25.0)
Attending physician	1,013 (46.6)	1,021 (47.0)	1,025 (47.8)	1,031 (47.4)
House staff	551 (25.4)	566 (26.0)	542 (25.3)	539 (24.8)
Advanced practice provider	592 (27.2)	575 (26.4)	568 (26.5)	597 (27.5)
Other	17 (0.8)	12 (0.6)	11 (0.5)	7 (0.3)
Medical center				
CU (4 hospitals)	1,305 (59.3)	1,307 (59.4)	1,296 (59.7)	1,291 (58.8)
WC (3 hospitals)	894 (40.7)	895 (40.6)	875 (40.3)	905 (41.2)
Order sessions (N=15,942,190)[a]	4,007,833 (25.1)	3,958,269 (24.8)	3,948,077 (24.8)	4,028,011 (25.3)
Orders per session, median (IQR)	2 (3)	2 (3)	2 (3)	2 (3)
Clinician role				
Attending physician	1,670,101 (42.1)	1,621,937 (41.6)	1,670,050 (42.7)	1,729,828 (43.3)
House staff	904,574 (22.8)	926,073 (23.7)	906,208 (23.1)	883,318 (22.1)
Advanced practice provider	1,393,888 (35.1)	1,353,297 (34.7)	1,338,452 (34.2)	1,377,587 (34.5)
Other	540 (0.0)	1,090 (0.0)	467 (0.0)	6,186 (0.2)
Clinical setting				
Emergency department	727,346 (18.1)	688,853 (17.4)	727,268 (18.4)	815,944 (20.3)
Inpatient	1,427,957 (35.6)	1,403,382 (35.5)	1,392,976 (35.3)	1,394,073 (34.6)
Outpatient	1,852,530 (46.2)	1,866,034 (47.1)	1,827,833 (46.3)	1,817,994 (45.1)
Photo available				
Yes	2,482,838 (61.9)	2,466,293 (62.3)	2,488,373 (63.0)	2,508,773 (62.3)
No	1,524,995 (38.1)	1,491,976 (37.7)	1,459,704 (37.0)	1,519,238 (37.7)
Patient age group, y[b]				
<1	145,366 (3.6)	152,610 (3.9)	139,811 (3.5)	143,038 (3.6)
1-19	394,853 (9.9)	384,016 (9.7)	343,498 (8.7)	430,751 (10.7)
20-49	1,121,667 (28.0)	1,131,980 (28.6)	1,105,674 (28.0)	1,149,328 (28.5)
50-69	1,237,908 (30.9)	1,221,097 (30.8)	1,237,978 (31.4)	1,226,730 (30.5)
≥70	1,108,039 (27.7)	1,068,563 (27.0)	1,121,115 (28.4)	1,078,163 (26.8)
Patient gender				
Female	2,213,263 (55.3)	2,181,824 (55.2)	2,203,082 (55.9)	2,226,622 (55.3)
Male	1,789,241 (44.7)	1,771,597 (44.8)	1,739,757 (44.1)	1,795,511 (44.6)
Other/unknown	5329 (0.0)	4848 (0.0)	5238 (0.0)	5878 (0.0)
Patient race				
Asian American/Pacific Islander	238,312 (5.9)	219,857 (5.6)	227,377 (5.8)	235,809 (5.9)
American Indian/Alaska Native	9,973 (0.2)	10,580 (0.3)	9,906 (0.3)	10,477 (0.3)
Black/African American	716,228 (17.9)	678,620 (17.1)	693,242 (17.6)	725,878 (18.0)
White	1,589,638 (39.7)	1,605,398 (40.6)	1,551,210 (39.3)	1,585,620 (39.4)
Other[c]/declined/unknown	1,453,682 (36.3)	1,443,814 (36.5)	1,466,342 (37.1)	1,470,227 (36.5)
Patient ethnicity				
Latino	1,061,418 (26.5)	1,050,733 (26.5)	1,105,686 (28.0)	1,096,150 (27.2)
Not Latino	2,372,766 (59.2)	2,335,226 (59.0)	2,303,964 (58.4)	2,370,648 (58.9)
Declined/unknown	573,649 (14.3)	572,310 (14.5)	538,427 (13.6)	561,213 (13.9)

	Arm 1 (Control) Storyboard no Photo/No Alert	Arm 2 Storyboard w Photo/No Alert	Arm 3 Storyboard no Photo/Alert w Photo	Arm 4 Storyboard w Photo/ Alert w Photo
Patient insurance status				
Commercial	1,370,328 (34.2)	1,400,024 (35.4)	1,296,849 (32.8)	1,380,095 (34.3)
Medicaid	919,528 (22.9)	890,316 (22.5)	913,571 (23.1)	943,797 (23.4)
Medicare	686,694 (17.1)	651,196 (16.5)	711,447 (18.0)	674,781 (16.8)
Other/unknown	1,031,283 (25.7)	1,016,733 (25.7)	1,026,210 (26.0)	1,029,338 (25.6)

[a]Row percent. [b]Missing age data for 5 order sessions (3 in Arm 2, 1 in Arm 3, 1 in Arm 4). [c]Other not described.
Note: Order sessions were balanced across study arms by hour of the day, day of the week, and quarter of the year (data not shown).

Principal Findings (cont'd). Table 2 shows patient characteristics of order sessions disaggregated by presence/absence of a photo at the time the orders were placed. Of note, 62.4% of order sessions overall were placed with a photo available. The distribution of covariates was similar in the photo and no photo conditions, with the exception of pediatric patients under the age of 1 year, as they had a lower proportion of photos taken.

Table 2. Patient Characteristics of Order Sessions With and Without Photos Available (Order Session Level)

Characteristic	Photo Available n=9,946,277	No Photo Available n=5,995,913	Overall N=15,942,190
Clinical setting			
Emergency department	1,883,657 (18.9)	1,075,754 (17.9)	2,959,411 (18.6)
Inpatient	3,500,601 (35.2)	2,117,787 (35.3)	5,618,388 (35.2)
Outpatient	4,562,019 (45.9)	2,802,372 (46.7)	7,364,391 (46.2)
Patient age group, y			
<1	125,842 (1.3)	454,983 (7.6)	580,825 (3.6)
1-19	822,667 (8.3)	730,451 (12.2)	1,553,118 (9.7)
20-49	2,897,286 (29.1)	1,611,363 (26.9)	4,508,649 (28.3)
50-69	3,272,116 (32.9)	1,651,597 (27.5)	4,923,713 (30.9)
≥70	2,828,366 (28.4)	1,547,519 (25.8)	4,375,885 (27.4)
Patient gender			
Female	5,616,550 (56.5)	3,208,241 (53.5)	8,824,791 (55.4)
Male	4,319,859 (43.4)	2,776,247 (46.3)	7,096,106 (44.5)
Other/unknown	9868 (0.1)	11,425 (0.2)	21,293 (0.1)
Patient race			
Asian American/Pacific Islander	581,369 (5.8)	339,986 (5.7)	921,355 (5.8)
American Indian/Alaska Native	25,521 (0.3)	15,415 (0.3)	40,936 (0.3)
Black/African American	1,826,451 (18.4)	987,517 (16.5)	2,813,968 (17.7)
White	3,949,793 (39.7)	2,382,073 (39.7)	6,331,866 (39.7)
Other/declined/unknown	3,563,143 (35.8)	2,270,922 (37.9)	5,834,065 (36.6)
Patient ethnicity			
Latino	3,009,728 (30.3)	1,304,259 (21.8)	4,313,987 (27.1)
Not Latino	5,833,131 (58.6)	3,549,473 (59.2)	9,382,604 (58.9)
Declined/unknown	1,103,418 (11.1)	1,142,181 (19.0)	2,245,599 (14.1)
Patient insurance status			
Commercial	3,213,337 (32.3)	2,233,959 (37.3)	5,447,296 (34.2)
Medicaid	2,286,815 (23.0)	1,380,397 (23.0)	3,667,212 (23.0)
Medicare	1,894,484 (19.0)	829,634 (13.8)	2,724,118 (17.1)
Other/unknown	2,551,641 (25.7)	1,551,923 (25.9)	4,103,564 (25.7)

Table 3 below shows patient characteristics at the patient level; as patients have orders placed for them by multiple clinicians over time, and may be represented in more than one study arm, Table 3 is not disaggregated by randomization group.

Outcomes. Figure 6 presents descriptive statistics of order sessions and rates of WP order sessions for the planned 4-arm ITT analysis and the stratified analyses by study arm and photo availability (presence/absence of a photo when orders were placed). Of the 15,942,190 order sessions included in the analysis, there were 23,300 WP orders sessions for an overall rate of 146.2 per 100,000 order sessions. For ease of reference, **Figure 6** also shows the photo configuration in each condition depending on whether a photo was available. For the ITT analysis, the intervention Arms 2, 3, and 4 include order sessions with a photo and order sessions without a photo. The additional primary and secondary analyses stratified the four study arms into conditions with photo (1Y, 2Y, 3Y, 4Y) and with no photo (1N, 2N, 3N, 4N). Comparisons and results for each of the four analyses are shown in **Figure 7** below.

Study Arm	Photo Available	Storyboard	Alert	Order Sessions	WP Order Sessions	WP Order Sessions per 100,000
ITT				15,942,190	23,300	146.2
Arm 1	+	GC		4,007,833	6,279	156.7
	–	GC				
Arm 2	+			3,958,269	5,836	147.4
	–	GC				
Arm 3	+	GC		3,948,077	5,587	141.5
	–	GC				
Arm 4	+			4,028,011	5,598	139.0
	–	GC				
Stratified						
Arm 1Y	+	GC		2,482,838	3,713	149.6
Arm 2Y	+			2,466,293	3,263	132.3
Arm 3Y	+	GC		2,488,373	3,297	132.5
Arm 4Y	+			2,508,773	3,227	128.6
Arm 1N	–	GC		1,524,995	2,566	168.3
Arm 2N	–	GC		1,491,976	2,573	172.5
Arm 3N	–	GC		1,459,704	2,290	156.9
Arm 4N	–	GC		1,519,238	2,371	156.1

Figure 6.Order Session Descriptive Statistics.

Table 3. Patient Characteristics (patient level)

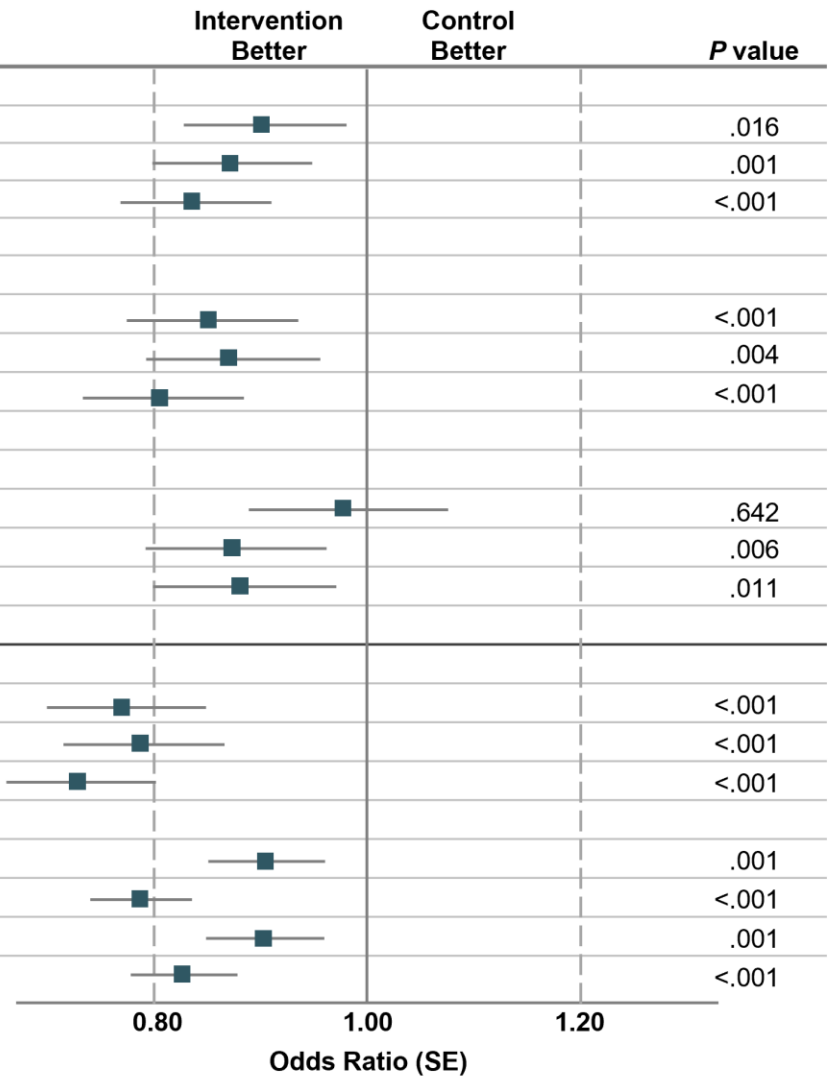
Characteristic	
Total patients, n	1,297,070
Order sessions per patient, median (IQR)	4 (8)
Age at first order, mean (SD)	44.3 (24.3)
Age group, y	
<1	53,662 (4.1)
1-19	182,867 (14.1
20-49	476,431 (36.7)
50-69	354,240 (27.3)
≥70	229,870 (17.7)
Gender	
Female	752,340 (58.0)
Male	542,825 (41.9)
Other/unknown	1905 (0.1)
Race	
Asian American/Pacific Islander	3,513 (0.3)
American Indian/Alaska Native	188,278 (14.5)
Black/African American	88,467 (6.8)
White	493,811 (38.1)
Other/declined/unknown	523,001 (40.3)
Ethnicity	
Latino	288,385 (22.2)
Not Latino	289,991 (22.4)
Declined/unknown	706,402 (55.4)

Primary Analyses

4-Arm ITT. In the planned ITT analysis, there was a significant reduction in WP order sessions in the intervention groups versus control: Storyboard with Photo (Arm 2) OR 0.90 (0.04), *P*<.05; Alert with Photo (Arm 3) OR 0.87 (0.04), *P*<.01; Storyboard and Alert with Photo (Arm 4) OR 0.84 (0.04), *P*<.001. Between-group comparisons were not statistically significant. These results demonstrate that patient photos displayed in the EHR significantly reduced wrong-patient order errors, even with the bias of incomplete compliance, as 37% of order sessions were placed without a patient photo available. Although the distribution of characteristics was balanced across randomization groups, we conducted an analysis adjusting for the variables in Table 1 out of an abundance of caution. The results were similar to those of the unadjusted analysis, with reductions differing by up to 1% (**Table 4 below**).

Figure 7. Results of Primary and Secondary Analyses (Order Session Level)

Primary Analyses	Comparisons	WP Order Sessions per 100,000	Odds Ratio (SE)	*P* value
ITT 4-Arm	Control Arm 1	156.7		
	Arm 2 vs 1	147.4	0.90 (0.04)	.016
	Arm 3 vs 1	141.5	0.87 (0.04)	.001
	Arm 4 vs 1	139.0	0.84 (0.04)	<.001
Stratified 2x4				
With Photo	Control Arm 1Y	149.6		
	Arm 2Y vs 1Y	132.3	0.85 (0.04)	<.001
	Arm 3Y vs 1Y	132.5	0.87 (0.04)	.004
	Arm 4Y vs 1Y	128.6	0.81 (0.04)	<.001
No Photo	Control Arm 1N	168.3		
	Arm 2N vs 1N	172.5	0.98 (0.05)	.642
	Arm 3N vs 1N	156.9	0.87 (0.04)	.006
	Arm 4N vs 1N	156.1	0.88 (0.04)	.011
Secondary Analyses				
Photo vs No-Photo Control				
	Arm 2Y vs 1N	132.3	0.77 (0.04)	<.001
	Arm 3Y vs 1N	132.5	0.79 (0.04)	<.001
	Arm 4Y vs 1N	128.6	0.73 (0.04)	<.001
Within Arm, Photo vs No Photo				
	Arm 1Y vs 1N	149.6	0.90 (0.03)	.001
	Arm 2Y vs 2N	132.3	0.79 (0.02)	<.001
	Arm 3Y vs 3N	132.5	0.90 (0.03)	.001
	Arm 4Y vs 4N	128.6	0.83 (0.03)	<.001



Primary Analyses (cont'd)

2×4 Stratified. In the 2×4 stratified analysis, we estimated the effect of the interventions with a photo available and without a photo available at the time the orders were placed. In the stratum with photos available, there were similar significant reductions in WP order sessions in the intervention groups versus control with photo available (1Y): Storyboard with Photo (Arm 2Y) OR 0.85 (0.04), *P*<.01; Alert with Photo (Arm 3Y) OR 0.87 (0.04), *P*<.01; Storyboard and Alert with Photo (Arm 4Y) OR 0.81 (0.04), *P*<.0001. Comparisons of Arms 2Y, 3Y, and 4Y versus 1Y demonstrate the effect of the intended intervention, removing the potential bias introduced by contamination as the display of non-intervention photos is equally distributed across study arms. In the stratum with no photos available, there was no effect noted for the comparison of Arm 2N versus 1N (OR 0.98, SE 0.05, *P*=.64); however, significant reductions were observed for Arms 3N (OR 0.87, SE 0.04, *P*=.006) and 4N (OR 0.88, SE 0.04, *P*=.011) versus 1N, demonstrating the effectiveness of the Alert in the absence of a patient photo.

Table 4. Primary Analyses Adjusted for Potential Confounding

	Adjusted OR	SE	*P* value
ITT			
Arm 2	0.89	0.04	.004
Arm 3	0.88	0.04	.003
Arm 4	0.84	0.04	<.001
Stratified			
Arm 2Y	0.85	0.04	<.001
Arm 3Y	0.90	0.04	.001
Arm 4Y	0.82	0.04	<.001

We conducted an analysis adjusting for the following variables identified as potential confounders, i.e., associated with both the 2×4 stratification (combination of randomized arm and photo availability) and the probability of the WP order session outcome: patient age; medical center; clinical setting; clinician role; hour of day, day of week, quarter of year; and number of orders in the order session. Adjusted analysis yielded results similar to the unadjusted analysis, with reductions differing by 3%–4% (**Table 4**).

Secondary Analyses

Intervention with Photo vs No-Photo Control. To estimate the maximum potential effect of patient photo interventions, we compared intervention Arms 2Y, 3Y, and 4Y (with photos available) versus control Arm 1N (no photos available). This analysis assumes all orders in the intervention arms are placed with a photo available and there are no photos available in the control arm, eliminating the potential for contamination by display of non-intervention photos in other EHR features. Compared with no-photo control, photo interventions yielded large and highly significant reductions of 21% to 27%: Arm 2Y OR 0.77 (0.04), Arm 3Y OR 0.79 (0.04), Arm 4Y OR 0.73 (0.04) (*P*<.001 all comparisons).

Within Arm, Photo vs No Photo. This analysis isolates the effect of the presence versus absence of photos within each study arm. All comparisons show a significant reduction in WP order sessions with versus without photos. Of note was a significant reduction within the control arm 1Y versus 1N (OR 0.90, SE 0.03, *P*=.001), suggesting the effect of contamination by non-intervention display of patient photos.

Aim 3: Toolkit Development. To support Aim 3, *develop a Toolkit to provide implementation guidance for displaying patient photos in EHRs,* we drew upon our experience and synthesized materials developed during implementation at NYP sites. The final manuscript is currently in process and includes various methods on how to optimize patient photo compliance in multiple patient environments. Also included is an addendum that provides specifications on how to capture a quality patient photo, checklists and templates, sample policies and workflows, and training and patient education materials. Case studies cover topics such as how COVID-19 affected photo capture, and challenges of capturing photos in the Emergency Department.

Patient Photo Implementation. The Columbia research team coordinated with Patient Services, Information Systems, and Operations at NYP study sites to obtain photos for all patients as the standard registration process and to achieve a high level of patient photo compliance. The research team worked with NYP operations to develop staff training and education materials, create and distribute patient education materials, develop and implement workflows and standard scripts, and develop and revise policies and procedures. In addition, IT personnel transferred more than 120,000 patient photos from Allscripts to Epic. NYP also utilized the function in Epic's patient portal, i.e., MyChart, which allows patients to upload their own photos. The research team worked with NYP IT leadership to approve an additional 25,000 photos that had been uploaded through MyChart. As described above in **Context**, over a 3-month period these targeted strategies

substantially and significantly increased the proportion of patients with photos in Epic from 30%–40% to 65%–75%. Photo capture has been adopted at the institutional level such that this high rate of photo compliance has been maintained with no additional efforts. Our experience demonstrates the feasibility and widespread scalability of this effective intervention to other health systems.

Patient Photo Compliance and Study Monitoring Reports. Photo compliance reports were developed and deployed to assess compliance with capturing patient photographs in the EPIC environment at the study sites. Reports included overall photo compliance across each hospital, compliance by department (or portal of entry), and compliance by registrar by opportunity (for patients presenting with no photo in the system). Additional reports were developed to monitor the study design, i.e., a report to capture all new ordering clinicians to randomize into a study arm, a report to quantify the number of order sessions per study arm to maintain balance, and a report to track clinician grouper assignments to make sure that clinicians did not change study arms during the course of the study.

Aim 3A: User Experience Evaluation. We conducted focus groups and interviews with registration staff at NYP to elicit their experience of capturing patient photos in the system used with Allscripts. Findings will be reported with the Allscripts RCT results. Regarding Epic, we are conducting subanalyses to further assess the effectiveness of patient photos based on variability in photo quality and based on the specific device used to place orders during the study period.

Quality of Patient Photos. Poor-quality photos may weaken the effect of the intervention; therefore, we worked with Patient Access and local IT personnel to improve the quality of patient photos uploaded. While the percentage of patients with photos in the EHR increased over the study period, a review of a sample of photos revealed that there was a wide range in the quality of photos captured. There were high-quality photos that would meet specifications for a government ID photo, e.g., solid or white background, no object obstructing the face, no other individual in the photo, face framed to occupy over 80% of the photo; however, there were poor-quality photos, e.g., with the face occupying less than 20% of the photo frame, the face obstructed by glasses or hats, other people or objects appearing in the background, and blurry or overly light or dark photos. We are planning two sub-studies of the RCTs to assess photo quality:

1. Comparing the quality of photos taken by patients vs those taken by Patient Access representatives using a tool created to score photo quality based on parameters of standard ID photos (e.g., clarity, visibility, frame, background).
2. Using facial recognition software against all patient photos (~1.5 million) at the study sites to identify aspects of photo quality that predict wrong-patient orders.

Effect of Intervention by Device. In Epic, clinicians may place orders using a specific application on a computer (i.e., “Hyperspace”), on a tablet (i.e., “Canto”), or on a smartphone (i.e., “Haiku”). The randomization and study interventions were active and functioning in all applications; however, photos viewed on a phone in Haiku were very small. We are extracting audit log data to classify study orders into these three categories based on the Epic device and application used to place the orders: Hyperspace, Canto, or Haiku. We will then conduct analyses to determine the proportion of orders placed using each device and whether there are differences in the effectiveness of the patient photo interventions by device used to place the order.

Discussion

This study was the first RCT to test the effectiveness of displaying patient photos in an EHR to reduce wrong-patient order errors. In the 4-Arm ITT analysis, photos showed a significant reduction in wrong-patient order errors in all intervention arms, with no statistically significant difference between arms. Similarly, results of the 2×4 Stratified analysis in the photo stratum showed significant reductions in all intervention arms, with an additional reduction relative to the ITT analysis of 3%–5% in Arm 2 (Storyboard with Photo) and Arm 4 (Storyboard and Alert with Photo) by eliminating the potential bias introduced by contamination. Finally, the analysis of Interventions with Photo vs No-Photo Control, designed to estimate the maximum potential effect of patient photos for reducing wrong-patient order errors, demonstrated substantial and significant reductions in all intervention arms up to 27%.

In all analyses, Storyboard and Alert with Photo yielded a further reduction in wrong-patient order sessions of approximately 5%–6% compared with Storyboard alone. However, comparisons between arms were not statistically significant, as the difference was small and the study was powered to detect an additional 15% reduction of Storyboard and Alert versus Storyboard alone. Of note, in the no photo stratum, the presence of the Alert significantly reduced wrong-patient order errors by 12%–13% despite the absence of a patient photo, which is consistent with results of prior studies.[9,19]

In addition to demonstrating the effectiveness of the intended study interventions, we were able to estimate the effect of potential contamination introduced by patient photos displayed in non-study interventions. Comparing the rate of wrong-patient order sessions with versus without a photo available within the control arm, we found a significant reduction of approximately 10%, suggesting effectiveness and providing support for expanding the display of patient photos to additional features. This study, conducted in a large integrated health system with a diverse patient population, demonstrated the ability to successfully implement patient photos at scale. Through targeted operational and organizational efforts over a 3-month period, we addressed barriers to implementation and increased proportion of patients with photos, achieving a sustained rate of over 75%, with similar proportions across patient subgroups by gender, race, ethnicity, and insurance status.

Conclusions
Patient photos displayed in standard features in the EHR significantly reduced wrong-patient order errors, with no statistically significant differences observed between interventions. System-wide implementation of patient photos is feasible and a high rate of compliance can be achieved by addressing operational barriers.

Significance
We hypothesized that the combined intervention of Storyboard and Alert with Photo would yield a substantially greater reduction in wrong-patient order errors compared with Storyboard with Photo alone. Given the small additional effect of the interruptive Alert compared to the passive intervention in Storyboard, and the burden of alert fatigue on clinicians, we advocate use of the passive intervention to maximize benefit and minimize burden on clinicians. Contamination by display of patient photos in additional EHR features (e.g., patient lists) appeared to provide reductions in addition to study interventions. These results support the widespread implementation of patient photos by health systems and the continued development and expansion of features to display patient photos by EHR vendors.

Implications
These results inform the revision and issuance of evidence-based health IT safety regulations and requirements. Although display of patient photos in EHRs has been recommended by regulatory bodies, this is the first rigorous evidence to support this safety practice.

List of Publications and Products (Bibliography of Published Works and Electronic Resources from Study)

Reuland BD, Redman CT, Kneifati-Hayek JZ, Fernandes Y, Kosber R, Ortuno-Garcia C, Crossman DJ, Salmasian H, Chen AR, Barchi DJ, Applebaum JR, Green RA, Adelman JS. Observation and patients' perceptions of incorporating their photograph into the electronic health record. *J Patient Saf*. 2022;18(5):377-381. PMID: 35948287.

Salmasian H, Blanchfield BB, Joyce K, Centeio K, Schiff GB, Wright A, Baugh CW, Schuur JD, Bates DW, Adelman JS, Landman AB. Association of display of patient photographs in the electronic health record with wrong-patient order entry errors. *JAMA Netw Open*. 2020;3(11):e2019652. PMID: 33175173; PMCID: PMC7658731

Bibliography/References Cited

1. Bates DW, Teich JM, Lee J, Seger D, Kuperman GJ, Ma'Luf N, Boyle D, Leape L. The impact of computerized physician order entry on medication error prevention. *J Am Med Inform Assoc.* 1999;6(4):313-321. PMID: 10428004. PMC61372.
2. Kaushal R, Shojania KG, Bates DW. Effects of computerized physician order entry and clinical decision support systems on medication safety: A systematic review. *Arch Intern Med.* 2003;163(12):1409-1416. PMID: 12824090.
3. Reckmann MH, Westbrook JI, Koh Y, Lo C, Day RO. Does computerized provider order entry reduce prescribing errors for hospital inpatients? A systematic review. *J Am Med Inform Assoc.* 2009;16(5):613-623. PMID: 19567798. PMC2744711.
4. Koppel R, Metlay JP, Cohen A, Abaluck B, Localio AR, Kimmel SE, Strom BL. Role of computerized physician order entry systems in facilitating medication errors. *JAMA.* 2005;293(10):1197-1203. PMID: 15755942.
5. Harrison MI, Koppel R, Bar-Lev S. Unintended consequences of information technologies in health care--an interactive sociotechnical analysis. *J Am Med Inform Assoc.* 2007;14(5):542-549. PMID: 17600093. PMC1975796.
6. 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;11(2):104-112. PMID: 14633936. PMC353015.
7. Ash JS, Sittig DF, Poon EG, Guappone K, Campbell E, Dykstra RH. The extent and importance of unintended consequences related to computerized provider order entry. *J Am Med Inform Assoc.* 2007;14(4):415-423. PMID: 17460127. PMC2244906.
8. Campbell EM, Sittig DF, Ash JS, Guappone KP, Dykstra RH. Types of unintended consequences related to computerized provider order entry. *J Am Med Inform Assoc.* 2006;13(5):547-556. PMID: 16799128. PMC1561794.
9. Adelman JS, Kalkut GE, Schechter CB, Weiss JM, Berger MA, Reissman SH, Cohen HW, Lorenzen SJ, Burack DA, Southern WN. Understanding and preventing wrong-patient electronic orders: A randomized controlled trial. *J Am Med Inform Assoc.* 2013;20(2):305-310. PMID: 22753810. PMC3638184.
10. Office of the National Coordinator for Health Information Technology. Patient identification SAFER guide Available at: https://www.healthit.gov/sites/default/files/safer_patient_identification.pdf. Accessed February 26, 2024.
11. Kanwisher N, Moscovitch M. The cognitive neuroscience of face processing: An introduction. *Cogn Neuropsychol.* 2000;17(1):1-11. PMID: 20945168.
12. 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;130(1):e211-219. PMID: 22665415.
13. Salmasian H, Blanchfield BB, Joyce K, Centeio K, Schiff GB, Wright A, Baugh CW, Schuur JD, Bates DW, Adelman JS, Landman AB. Association of display of patient photographs in the electronic health record with wrong-patient order entry errors. *JAMA Netw Open.* 2020;3(11):e2019652. PMID: 33175173. PMC7658731.
14. Sittig DF, Salimi M, Aiyagari R, Banas C, Clay B, Gibson KA, Goel A, Hines R, Longhurst CA, Mishra V, Sirajuddin AM, Satterly T, Singh H. Adherence to recommended electronic health record safety practices across eight health care organizations. *J Am Med Inform Assoc.* 2018;25(7):913-918. PMID: 29701854. PMC7647041.
15. National Quality Forum. Patient safety 2015: Final technical report. Available at: https://www.qualityforum.org/Publications/2016/02/Patient_Safety_2015_Final_Report.aspx. Accessed February 27, 2024.
16. Adelman JS, Applebaum JR, Schechter CB, Berger MA, Reissman SH, Thota R, Racine AD, Vawdrey DK, Green RA, Salmasian H, Schiff GD, Wright A, Landman A, Bates DW, Koppel R, Galanter WL, Lambert BL, Paparella S, Southern WN. Effect of restriction of the number of concurrently open records in an electronic health record on wrong-patient order errors: A randomized clinical trial. *JAMA.* 2019;321(18):1780-1787. PMID: 31087021. PMC6518341.
17. Adelman J, Aschner J, Schechter C, Angert R, Weiss J, Rai A, Berger M, Reissman S, Parakkattu V, Chacko B, Racine A, Southern W. Use of temporary names for newborns and associated risks. *Pediatrics.* 2015;136(2):327-333. PMID: 26169429.

18. Adelman JS, Aschner JL, Schechter CB, Angert RM, Weiss JM, Rai A, Berger MA, Reissman SH, Yongue C, Chacko B, Dadlez NM, Applebaum JR, Racine AD, Southern WN. Evaluating serial strategies for preventing wrong-patient orders in the NICU. *Pediatrics.* 2017;139(5):e20162863. PMID: 28557730.
19. Green RA, Hripcsak G, Salmasian H, Lazar EJ, Bostwick SB, Bakken SR, Vawdrey DK. Intercepting wrong-patient orders in a computerized provider order entry system. *Ann Emerg Med.* 2015;65(6):679-686 e671. PMID: 25534652. PMC4447590.
20. Kannampallil TG, Manning JD, Chestek DW, Adelman J, Salmasian H, Lambert BL, Galanter WL. Effect of number of open charts on intercepted wrong-patient medication orders in an emergency department. *J Am Med Inform Assoc.* 2018;25(6):739-743. PMID: 29025090. PMC7646860.
21. Adelman JS, Applebaum JR, Southern WN, Schechter CB, Aschner JL, Berger MA, Racine AD, Chacko B, Dadlez NM, Goffman D, Babineau J, Green RA, Vawdrey DK, Manzano W, Barchi D, Albanese C, Bates DW, Salmasian H. Risk of wrong-patient orders among multiple vs singleton births in the neonatal intensive care units of 2 integrated health care systems. *JAMA Pediatr.* 2019;173(10):979-985. PMID: 31449284. PMC6714004.
22. Kern-Goldberger AR, Kneifati-Hayek J, Fernandes Y, Applebaum JR, Schechter CB, Adelman JS, Goffman D. Wrong-patient orders in obstetrics. *Obstet Gynecol.* 2021;138(2):229-235. PMID: 34237762.
23. Institute for Healthcare Improvement. Leading a culture of safety: A blueprint for success. Available at: https://www.ihi.org/resources/publications/leading-culture-safety-blueprint-success. Accessed March 23, 2024.
24. Institute of Medicine Committee on Patient Safety and Health Information Technology. *Patient safety: Achieving a new standard for care.* Washington, D.C.: National Academies Press (US); 2004.
25. Leape L, Abookire S. Who draft guidelines for adverse event reporting and learning systems: From information to action. Available at: http://apps.who.int/iris/bitstream/handle/10665/69797/WHO-EIP-SPO-QPS-05.3-eng.pdf?sequence=1&isAllowed=y. Accessed March 23, 2024.
26. National Association for Healthcare Quality. National association for healthcare quality (NAHQ) issues 'call to action' for enhancing health care quality and patient safety. Available at: http://www.prnewswire.com/news-releases/national-association-for-healthcare-quality-nahq-issues-call-to-action-for-enhancing-health-care-quality-and-patient-safety-174423331.html. Accessed March 23, 2024.
27. World Health Organization. Global priorities for patient safety research: Better knowledge for safer care. Available at: https://www.who.int/publications/i/item/9789241598620. Accessed March 23, 2024.
28. 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.
29. Reuland BD, Redman CT, Kneifati-Hayek JZ, Fernandes Y, Kosber R, Ortuno-Garcia C, Crossman DJ, Salmasian H, Chen AR, Barchi DJ, Applebaum JR, Green RA, Adelman JS. Observation and patients' perceptions of incorporating their photograph into the electronic health record. *J Patient Saf.* 2022;18(5):377-381. PMID: 35948287.
30. Aseem S, Ratrout BM, Litin SC, Ganesh R, Croghan IT, Salerno MS, Majka AJ, Chutka DS, Hurt RT, Abu Lebdeh HS, Vincent A, Nanda S. A process of acceptance of patient photographs in electronic medical records to confirm patient identification. *Mayo Clin Proc Innov Qual Outcomes.* 2020;4(1):99-104. PMID: 32055775. PMC7010970.
31. Aspden P, Corrigan JM, Wolcott J, Erickson SM, eds. *Patient safety: Achieving a new standard for care.* Washington (DC): National Academies Press (US); 2004.
32. Quality Interagency Coordination Task Force. Doing what counts for patient safety: Federal actions to reduce medical errors and their impact. Available at: https://archive.ahrq.gov/quic/Report/errors6.pdf. Accessed March 23, 2024.
33. Institute for Healthcare Improvement. Create a reporting system. Available at: https://staff.ihi.org/resources/Pages/Changes/CreateaReportingSystem.aspx. Accessed March 23, 2024.