# FINAL REPORT

**Title**: Electronic Health Record Use, Work Environments & Patient Outcomes

**Principal Investigator**: Ann Kutney-Lee

**Team Members**: Linda H. Aiken, Kathryn Bowles, Douglas Sloane, Lawton Burns

**Organization**: University of Pennsylvania

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**Federal Project Officer**: Shafa Al-Showk

# 1. STRUCTURED ABSTRACT

**Purpose:** The purpose of this study was to investigate the relationships between electronic health record (EHR) adoption and usability, work environment, and patient and nurse outcomes. This study aimed to understand the organizational conditions under which EHRs function best in hospitals.

**Scope:** Our understanding of the relationship between EHR use and patient outcomes remains limited. The influence of sociotechnical factors, such as the work environment, on these relationships has been understudied. Further, little research has addressed how EHR use affects clinician wellbeing.

**Methods:** This study employed retrospective, cross-sectional and panel design to study these relationships in hundreds of hospitals across four states using unique nurse survey data linked with the American Hospital Association Annual Survey and Information Technology Databases, and administrative patient discharge data.

**Results:** Adoption of a comprehensive EHR system was associated with higher usability ratings and nurse-reported quality of care. Independent of the EHR adoption level, the work environment was also highly associated with nurses' ratings of EHR usability and quality of care. In fully adjusted models, we noted that, in most cases, the effect of EHR adoption level was attenuated and sometimes rendered insignificant, suggesting that the work environment plays a significant mediating role in the relationship between EHR adoption level and nurse ratings of usability and quality of care. In our analysis of patient and nurse outcomes, EHR usability was a stronger predictor of outcomes than EHR adoption level, including nurse burnout and surgical patient mortality.

**Key Words**: electronic health records, usability, nursing, outcomes, hospital

## 2. PURPOSE

Electronic health records (EHRs) have been implemented rapidly over the past decade with the great promise of improving healthcare quality and safety; however, evidence of greater EHR use on patient outcomes has been inconclusive to date.[1-4] One potential reason that EHR adoption has not resulted in widespread improvements in care is that systems may be implemented without fully considering existing organizational structures. Institutional characteristics, such as managerial support, organizational climate, and staffing resources are key to the successful implementation of new technologies.[5] Yet, there has been little attention in the empirical literature related to EHR implementation on the role of the work environment, particularly of nurses— the largest group of care providers and EHR users in hospitals. The overall purpose of this project was to investigate the relationships between EHR use (i.e. adoption and usability), work environment factors, and patient outcomes. The study aimed to determine not only whether EHR adoption and usability were related to outcomes, but also to better understand the organizational conditions under which EHRs function best in hospitals.

Since the project was funded, multiple reports have emerged regarding the alarming rates of clinician burnout.[6-7] Most recently, the National Academy of Medicine's [6] report, "Taking Action Against Burnout: A Systems Approach to Professional Well-Being," specifically recognized EHR usability as a contributing work system factor. Given our unique nurse survey data containing information on these factors, we capitalized upon the opportunity to also examine the effects of EHR adoption and usability on nurse job outcomes, including burnout.

Three primary analyses emerged from the project:

1) EHR adoption and nurse reports of usability and quality of care: The role of work environment
2) EHR adoption level and usability: Effects on patient and nurse outcomes
3) Effects of changes in EHR adoption levels on changes in patient outcomes over time

## 3. SCOPE

The use of health information technology (HIT), including EHRs, is a promising and widely promoted strategy for hospitals to improve care provision and coordination, and ultimately patient outcomes related to safety and quality.[8] The federal government has been one of the strongest proponents of hospitals' EHR adoption and has made significant financial investments to create a digital infrastructure for the country's healthcare system. The Health Information Technology for Economic and Clinical Health (HITECH) Act in 2009 provided hospitals and other providers with financial grants and incentives totaling an estimated $27 billion to adopt EHRs [9] and spurred the rapid adoption of EHR systems into hospitals.[10]

Despite the anticipated benefits and rapid uptake of EHR systems, our understanding of the relationship between the adoption of EHR systems and patient outcomes remains limited and unclear.[1-4] An international synthesis of systematic reviews on HIT, including EHRs, concluded that there is little empirical evidence to support its purported benefits, particularly for patient safety and quality of care.[11] The existing literature base is limited in a number of ways. First, many evaluation studies have been performed in single institutions, and do not provide insight into whether, and how, the benefits of EHR adoption depend on differences in organizational context. Of the larger studies that have been conducted, the study timeframes ended prior to the HITECH Act.[12,13] Thus, much of the evidence that we currently have is based primarily on hospitals known as "early adopters" that may have been more likely to provide higher quality of

care regardless of the EHR system. Another significant limitation of the existing literature is the lack of empirical work on the influence of sociotechnical factors on EHR implementation, including how the interplay between technology and the work environment affects patient outcomes. A wide range of articles on HIT effectiveness, from case studies to systematic reviews, strongly suggests that the work environment is a highly influential factor to the successful implementation of an EHR system but is often overlooked by researchers and administrators alike.[14,15]

In addition to a lack of patient outcome studies, little research has addressed how EHR use affects clinicians. Reports of the unintended consequences of EHR use, including issues with usability and increased documentation burden on providers are growing, particularly among physicians.[6,16,17] We aimed to examine this phenomenon among nurses—another large group of EHR end-users. As EHRs have now become ubiquitous, our study provided a current evaluation of the relationships among EHR adoption and usability, the work environment, and patient and nurse outcomes.

## 4. METHODS

### Study Design

The study employed a retrospective, cross-sectional design to examine the associations between EHR adoption, usability, work environments and outcomes, using administrative patient data, nurse survey data and the AHA Annual Survey and Information Technology Database in 2015/2016 (Analyses 1 and 2). We used a retrospective, panel design using the 2015/2016 data as well as similarly collected data from 2006/2007 to examine the relationship between EHR adoption and patient outcomes in a panel of over 200 hospitals (Analysis 3). This project and the parent studies under which the nurse survey data were collected received human subjects approval from the University of Pennsylvania Institutional Review Board.

### Data Sources

*Nurse Survey Data*. In 2006/2007 and 2015/2016, random samples of registered nurses (RNs) in California (CA), Pennsylvania (PA), New Jersey (NJ), and Florida (FL) were mailed a self-administered paper survey to their homes as part of the RN4CAST studies. Major categories of questions on the survey included: 1) characteristics of the respondent's present position and demographic information; 2) the Practice Environment Scale of the Nursing Work Index (PES-NWI);[18] 3) the Maslach Burnout Inventory,[19] and 4) questions related to EHR system usability (collected in 2016 only). Respondents who worked in hospitals identified their primary employer which allowed for linkages to administrative and patient discharge data. Details about the RN4CAST survey methodology have been published elsewhere.[20,21]

*AHA Information Technology (IT) Database.* The AHA IT Database provides information on hospitals' adoption of EHR components, including electronic clinical documentation (e.g. medication lists, nursing notes), results viewing (e.g. labs, radiology), decision support (e.g. clinical guidelines, drug alerts), bar coding (e.g. labs, medications) and computerized provider order entry (CPOE). The data specify the degree to which these functions are implemented within the hospital and have been collected since 2007.

*AHA Annual Survey.* The AHA Annual Survey collects information on organizational structure, facilities and services, total beds, utilization, finances, and staffing for all hospitals in the U.S., including non-AHA members.

*Administrative Patient Data*.  Comprehensive patient data were obtained for 2006/2007 and 2015/2016 from each of the four state agencies, including the Office of Statewide Health Planning and Development (OSHPD) in CA, the Agency for Health Care Administration (AHCA) in FL, New Jersey Department of Health and Senior Services (NJDHSS), and the Pennsylvania Health Care Cost Containment Council (PHC4). These data include patient demographics, diagnosis and procedure codes, and mortality information.

**Study Population**

*Nurses.* Respondents to the nurse survey who reported working in a hospital as a staff nurse providing direct patient care were included in the analysis.

*Patients*. Administrative patient databases from the four states were used to identify patients 18 years of age and older with a diagnosis related group (DRG) classification of general, orthopedic, or vascular surgery.

*Hospitals*. Our analysis included adult, non-federal acute care hospitals in CA, PA, NJ, and FL. Hospitals were included in the analysis if they had at least 10 nurse survey respondents to ensure reliable estimates of organizational factors, and if the hospital was represented in the AHA and AHA IT Databases.

**Measures**

*Patient Outcomes*.  In analysis 2, two primary patient outcome variables were examined using the administrative patient data: inpatient mortality and 30-day readmission.  The primary outcome for analysis 3 (the panel study using data from two points in time) was risk-adjusted inpatient mortality rates that were calculated and analyzed at the hospital level.

*Nurse-reported quality and safety outcomes.* On the nurse survey, respondents were asked to rate the quality of care provided in their work setting on a 4-point Likert scale of excellent, good, fair, or poor. Using an item adapted from the Agency for Healthcare Research and Quality's Patient Safety Culture Survey,[22] nurses assigned an overall grade for their unit on patient safety as: A: excellent; B: very good; C: acceptable; D: poor; or F: failing.

*Nurse outcomes.* For Analysis 2, three nurse job outcomes derived from the nurse survey were examined: burnout, job dissatisfaction, and intention to leave. The 9-item emotional exhaustion subscale of the Maslach Burnout Inventory[19] was used to measure nurse burnout. Nurses were considered to have "high" burnout who had a score of 27 or above on the emotional exhaustion subscale. A single item that asked about the degree to which nurses were satisfied with their jobs was used to measure job satisfaction. Intention to leave was measured using a single item that asked whether the respondent was planning on changing jobs in the next year.

*EHR Adoption*.  Using the AHA IT Database, we classified hospitals into two groups based on their reported EHR adoption level: 1) basic system or less, or 2) comprehensive system. Following definitions provided by the Office of the National Coordinator for Health Information Technology,[23] hospitals were classified as having a basic EHR if the following were either fully implemented on at least one clinical unit or across all units: 1) electronic clinical documentation of demographics, problem lists, medication lists, and discharge summaries, 2) electronic laboratory, radiologic and diagnostic test results, and 3) CPOE. Given most hospitals have some form of EHR technology,[23] we combined hospitals with a basic EHR system with those that did not meet the requirements of a basic system. Comprehensive EHR systems were defined as the presence of the three core components of a basic system (i.e. electronic clinical

documentation of demographics, problem lists, medication lists, and discharge summaries; electronic laboratory, radiologic and diagnostic test results, and CPOE), as well as 14 additional functionalities that have been implemented fully across all units.

*Changes in EHR Adoption.* For Analysis 3, hospital EHR adoption level was obtained from the AHA IT Database in both study periods and was used to produce a variable that indicated change in EHR adoption status over time. By taking the difference in values between time 1 (2006/2007) and time 2 (2015/2016), we were able to estimate how hospitals moved from, for example: no EHR system to a basic system, a basic system to a comprehensive system, etc.

*EHR Usability.* On the nurse survey, respondents were asked to indicate their level of agreement with a set of 7 items adapted from previous studies [24,25] that measured evaluations of the system's <u>usability</u>. On a 4-point Likert scale ranging from 'strongly agree' to 'strongly disagree', nurses reported on: ability to quickly access patient information, interference of the system in the provision of care, ease of use, trust in the accuracy of patient assessment and medication information, the system's ability to support work efficiency, and the ability of the system to easily share information between team members. While analysis 1 examined these items individually, analysis 2 employed these 7 items to create a hospital-level measure. Individual item ratings were averaged across all nurses within a hospital to create a hospital-level EHR usability score that demonstrated high internal consistency (Cronbach's alpha=0.87). On the survey, nurse respondents also rated their <u>satisfaction</u> with their current patient record system on a 4-point Likert scale ranging from 'very satisfied' to 'very dissatisfied'.

*Nurse work environment.* The nurse work environment was measured using the Practice Environment Scale of the Nursing Work Index (PES-NWI), a 31-item instrument.[18] The items ask nurses to indicate the degree to which various organizational features are present in their practice setting. Hospital-level organizational measures were created by aggregating the nurses' responses on items that comprise specific subscales and calculating summary measures for each hospital. The PES-NWI subscales include nurse participation in hospital affairs (9 items), nursing foundations for quality care (10 items), nurse manager ability, leadership, and support of nurses (5 items), staffing and resource adequacy (4 items), and collegial nurse-physician relations (3 items).[18] A PES composite score for each hospital was created by calculating the mean of the five hospital-level subscales. We used the PES composite score to categorize hospital work environments as follows: better (>75th percentile), mixed (26th -74th percentile), and poor (<25th percentile).

*Risk adjustment.* In analysis 1, nurse-reported quality and safety outcomes were risk adjusted for structural hospital characteristics (size, teaching status, technology status, state, and ownership) and individual nurse characteristics (age, sex, years of RN experience, unit type, and education level of a bachelor's degree in nursing or higher). Using responses from the nurse survey, we also accounted for nurse staffing by creating a hospital-level measure that was derived by dividing the average number of patients present on each unit during the last shift divided by the average number of RNs present on the last shift. In analysis 2, the outcomes of inpatient mortality and readmissions were risk-adjusted for a set of patient characteristics, including: age, sex, surgical DRG, and a comprehensive set of 29 comorbidities based on the model developed by Elixhauser[26] as used by Volpp and colleagues[27], and structural hospital characteristics. The nurse outcome models adjusted for the structural hospital and nurse characteristics outlined above. In analysis 3, hospital-level mortality rates were risk-adjusted for the same set of patient characteristics used in analysis 2.

**Data Analysis**

**1) EHR adoption and nurse reports of usability and quality of care: The role of work environment (cross-sectional analysis of 2015/2016 data)**

Individual EHR usability items and nurse-reported quality and safety outcomes were examined descriptively for nurses who worked in hospitals with and without comprehensive EHRs and by work environment classification. Robust logistic regression models that accounted for the clustering of nurses within hospitals were used to examine the effect of comprehensive EHR system adoption and the work environment on outcomes, first separately, then jointly, and finally in a fully adjusted model that accounted for other hospital and nurse characteristics. An interaction term between comprehensive EHR system adoption and work environment was tested but was not statistically significant.

**2) EHR adoption level and usability: Effects on patient and nurse outcomes (cross-sectional analysis of 2015/2016 data)**

Our primary independent variables in this analysis were EHR adoption level (comprehensive vs. basic/none) and hospital-level EHR usability. Our dependent variables were a set of three nurse job outcomes (burnout, job dissatisfaction, and intention to leave) and two patient outcomes (surgical inpatient mortality and 30-day readmission). The hospital-level EHR usability measure had a mean score of 2.1 (SD=0.29) and a range of 1.35-2.91. To facilitate interpretation, we categorized hospital EHR usability as poorer (<=25% percentile), moderate (26th-74th percentile), and better (>=75th percentile).

After describing the variables of interest and bi-variate relationships, we used robust logistic regression models to examine the independent and joint effects of EHR adoption and usability on patient and nurse outcomes in unadjusted and fully adjusted models that accounted for potential confounding variables as outlined in the Measures section.

**3) Effects of changes in EHR adoption levels on changes in patient outcomes over time (panel analysis of 2006/2007and 2015/2016 data)**

The analytic dataset for the panel study consisted of hospital-level measures of EHR adoption levels, nursing organization (i.e. work environment) and risk-adjusted rates of inpatient mortality for each time period (2006/2007 and 2015/2016). We then constructed difference measures for each hospital to measure the direction and magnitude of the change in each variable of interest. The dataset also included codes for the (largely) fixed hospital characteristics (size, technology, and teaching status) for the different hospitals in the two time periods. We chose to use a two-period difference model to estimate the changes in patient outcomes that were associated with changes in EHR adoption levels. Using a difference model approach effectively accounted for all unmeasured variables that did not change over time.

**Limitations**

This study was limited by the cross-sectional nature of the data, particularly related to EHR usability. Although we were able to assess the effect of EHR adoption on patient mortality using two time points of data, three or more are often necessary to provide a more complete assessment of causal trends. Even though a fixed effects difference model approach was employed, the potential for unmeasured variable bias exists. Hospitals may have changed over time in ways that affected changes in mortality that were not captured by our data. Further,

surgical mortality rates decreased significantly by 2015/2016 which may have significantly affected our power to detect any significant changes. Another key limitation of our analyses was that we were unable to account for the time since the EHR system was adopted or account for any changes in systems that may have occurred during the study period. A recent study demonstrated that positive effects of EHR are achievable, but that systems may take time to mature.[10] Finally, we were unable to examine the independent effect of work environment in our analysis of patient outcomes due to a high correlation with the EHR usability measure (as confirmed in our findings from Analysis 1).

## 6. RESULTS

**1) EHR adoption and nurse reports of usability and quality of care: The role of work environment (published in *Applied Clinical Informatics*)**

Our sample for this analysis consisted of 12,377 nurses in 353 hospitals. Approximately 44% of hospitals (n=157) in our sample had adopted a comprehensive EHR system in 2015/2016. Overall, one-quarter (25.1%) of surveyed nurses in the sample expressed dissatisfaction with their EHR system. Over half (55.4%) of nurses reported that EHRs interfered with patient care, while nearly one-third (31.9%) reported that they were not easy to use and did not help them to do their work in an efficient way (32.2%). Nearly half (48.5%) of survey respondents reported that nurses were not involved in choosing or modifying their record system.

Across all outcomes studied, the percentages of nurses reporting poor satisfaction with the EHR and unfavorable usability outcomes were significantly lower in hospitals with comprehensive systems compared with hospitals with a basic EHR or less. For example, the percentage of nurses reporting dissatisfaction with the EHR was lower in hospitals with comprehensive systems (21.6% vs.28.7%, p <0.001). Compared with hospitals with basic EHR systems or less, fewer nurses in hospitals with comprehensive systems reported poor quality of care (9.9% vs.14.0%, p< 0.001) and gave their hospital a poor patient safety grade (26.5% vs.30.3%, p<0.001).

Particularly notable were the differences in EHR satisfaction and usability ratings by work environment quality (see **Table 1**). Nearly 40% of nurses working in hospitals with poor work environments reported dissatisfaction with the system compared with less than 20% of nurses working in hospitals with better environments. Nearly half of nurses (45.6%) working in poor environments reported that the EHR system did not help them to work efficiently, compared with one-quarter (25.2%) of nurses in better environments. In hospitals with poor work environments, over two-thirds (67.6%) of nurses reported that nurses were not involved in choosing or modifying the record system compared with about one-third (34.4%) of nurses working in better conditions.

**Table 1.** Nurse Assessments of Electronic Health Record (EHR) Usability in Hospitals by Work Environment

| Usability Outcomes | All (n=12,377) | N (%) of nurses agreeing with statement who work in hospitals with a work environment that is: | | |
|---|---|---|---|---|
| | | Poor (n=2256) | Mixed (n=6214) | Better (n=3907) |
| Not satisfied with the patient record system | 2597 (25.1%) | 730 (38.6%) | 1282 (24.7%) | 585 (17.9%) |
| | | | | |
| The systems do not make it easy to access a patient's clinical data quickly | 2034 (19.7%) | 557 (29.7%) | 1001 (19.3%) | 476 (14.6%) |
| | | | | |
| The systems interfere with the provision of patient care | 5668 (55.4%) | 1146 (61.9%) | 2874 (55.8%) | 1648 (51.2%) |
| | | | | |
| The systems are not easy to use | 3290 (31.9%) | 816 (43.5%) | 1657 (31.9%) | 817 (25.1%) |
| | | | | |
| I do not trust the accuracy of the patient assessment data documented in the systems | 1802 (17.5%) | 522 (27.8%) | 883 (17.0%) | 397 (12.2%) |
| | | | | |
| I do not trust the accuracy of the medication information in the systems | 1145 (11.1%) | 313 (16.7%) | 579 (11.2%) | 253 (7.8%) |
| | | | | |
| The systems do not help me to do my work in an efficient way | 3321 (32.2%) | 854 (45.6%) | 1649 (31.8%) | 818 (25.2%) |
| | | | | |
| The systems do not make it easy to share information in a timely way with other members of the healthcare team | 2107 (20.5%) | 559 (29.8%) | 1055 (20.4%) | 493 (15.2%) |
| | | | | |
| Nurses were not involved in choosing (or modifying) the patient record system | 3183 (48.5%) | 819 (67.6%) | 1641 (50.5%) | 723 (34.4%) |
| | | | | |

**Note**: P-values generated from chi-squares. All differences significant at p<0.001. Percentages in "All" column may not align with overall sample size due to missing data. Sample sizes range from 6565 to 10495.
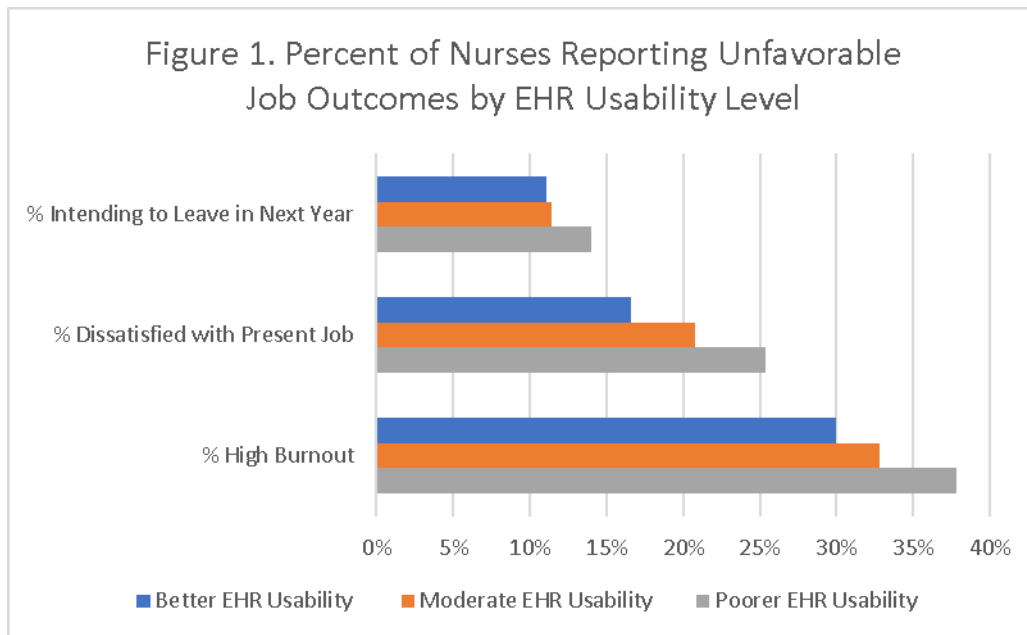
In fully-adjusted regression models, comprehensive EHR adoption was associated with lower odds of nurses reporting unfavorable usability outcomes, such as dissatisfaction with the system [odds ratio (OR) 0.75, 95% confidence interval (CI) 0.61 to 0.92]. We found that the quality of the nurse work environment also has an independent and statistically significant effect on nurses' reports of EHR usability, even after accounting for EHR adoption level. In fully adjusted models, the work environment was associated with all usability outcomes, with nurses in better

environments being less likely to report negatively. Comprehensive EHRs (OR 0.83, 95%CI 0.71 to 0.96) and better work environments (OR 0.47, 95%CI 0.42 to 0.52) were associated with lower odds of nurses reporting fair/poor quality of care, while poor patient safety grade was associated with the work environment (OR 0.50, 95%CI 0.46 to 0.54), but not EHR adoption level.

## 2) EHR adoption level and usability: Effects on patient and nurse outcomes (*Manuscript under review*)

The final sample for Analysis 2 included12,004 nurses and 1,281,848 patients nested within 343 hospitals across the four states.

**Figure 1** graphically displays the percentage of nurses reporting unfavorable job outcomes by EHR usability level. Compared with hospitals with better/moderate EHR usability, greater percentages of nurses working in hospitals with poorer EHR usability reported experiencing high burnout, job dissatisfaction and intention to leave their job in the next year. For example, the percentage of nurses reporting high levels of burnout was nearly10 points higher in hospitals with poorer EHR usability compared with hospitals with better usability (38% vs. 30%). All differences were significant at p<0.001.



Figure 1. Percent of Nurses Reporting Unfavorable Job Outcomes by EHR Usability Level

**Table 2** presents the results from the unadjusted and adjusted regression models for the nurse job outcomes. In unadjusted models, poorer EHR usability was significantly associated with the three outcomes.  Adoption of a comprehensive EHR system was associated with lower odds of intention to leave (OR 0.83, 95% CI 0.72 to 0.95). In the fully adjusted models, nurses working in hospitals with poorer usability were 41% more likely (OR 1.41, 95% CI 1.21 to 1.64) than nurses working in hospitals with better usability to report high burnout. Nurses working in hospitals with comprehensive EHR systems also had higher odds of burnout (OR 1.14, 95% CI

1.01 to 1.28) compared with nurses working in hospitals with less sophisticated systems. Similarly, strong relationships were observed between poorer EHR usability and higher odds of job dissatisfaction and intention to leave. EHR adoption level did not have a statistically significant effect on job dissatisfaction and intention to leave in the fully adjusted models.

| **Table 2.** Effects of Electronic Health Record (EHR) Usability and EHR Adoption Level on Nurse Job Outcomes (n=12,004 nurses) | | |
|---|---|---|
| | **Unadjusted, Estimated Separately** | **Fully Adjusted** |
| **Outcome** | **Odds Ratio (95% Confidence Interval)** | **Odds Ratio (95% Confidence Interval)** |
| **Burnout** EHR Usability (ref: Better) | | |
| Poorer | 1.42(1.23 to 1.63)*** | 1.41 (1.21 to 1.64)*** |
| Moderate | 1.14 (1.00 to 1.30)* | 1.14 (1.00 to 1.30) † |
| Comprehensive EHR (ref: basic or less) | 1.01 (0.90 to 1.14) | 1.14 (1.01 to 1.28)* |
| **Job Dissatisfaction** EHR Usability (ref: Better) | | |
| Poorer | 1.71 (1.45 to 2.02)*** | 1.61 (1.37 to 1.90)*** |
| Moderate | 1.32(1.12 to 1.55)*** | 1.24 (1.07 to 1.44) ** |
| Comprehensive EHR (ref: basic or less) | 0.98 (0.85 to 1.12) | 1.09 (0.96 to 1.23) |
| **Intent to Leave** EHR Usability (ref: Better) | | |
| Poorer | 1.30 (1.10 to 1.55)** | 1.31 (1.09 to 1.58)** |
| Moderate | 1.02 (0.86 to 1.21) | 1.04 (0.87 to 1.24) |
| Comprehensive EHR (ref: basic or less) | 0.83 (0.72 to 0.95)** | 0.88 (0.76 to 1.01) † |
| **Notes: *** $p \leq 0.001$ ** $p \leq 0.01$, * $p \leq 0.05$, †$p<0.10$. Odds ratios are from robust logistic regression models adjusted for hospital characteristics (size, teaching status, high-technology procedure capability, state, nurse staffing level, % of nurses with bachelor's degree or higher), nurse characteristics (age, sex, years of RN experience, unit type(medical/surgical, intensive care, other) and the clustering of nurses within hospitals.** | | |

We also assessed the effect of EHR usability and adoption level on surgical patient outcomes. We observed that poorer usability has detrimental effects on patient mortality and readmissions following common surgery. We did not observe a statistically significant effect of EHR adoption level on the patient outcomes.

## 3) Effects of changes in EHR adoption levels on changes in patient outcomes over time

The sample for the panel study in analysis 3 consisted of 220 hospitals for which we had nurse survey (at least 10 respondents), patient discharge data, and AHA Annual Survey and IT Database information in both 2006/2007 and 2015/2016. The records of over 2.8 million surgical

patients across both study years were used to construct risk-adjusted inpatient mortality rates for study hospitals.

**Table 3** shows how hospitals in the sample changed in their EHR adoption levels and surgical mortality rates over the study period. Over 40% (n=93) of hospitals in the sample made major progress in EHR system implementation, moving from no EHR to a comprehensive system between study time periods. Although the average changes in surgical mortality rates within each of EHR change categories were in the hypothesized direction, these changes were not statistically significant (see limitations).

| **Table 3.** Change in Electronic Health Record (EHR) Adoption Levels and Surgical Mortality Rates in Study Hospitals between 2006/2007 and 2015/2016 (n=224) | | | |
|---|---|---|---|
| **Change in EHR Level** | **N (%)** | **Average Change in Surgical Mortality Rate (%)** | **P-value** |
| None to Basic EHR/ Basic EHR to Comprehensive EHR | 85 (38.0%) | 0.26 | 0.54 |
| None to Comprehensive EHR | 93 (41.5%) | -0.17 | 0.68 |
| No change | 42 (18.8%) | 0.79 | 0.20 |
| Reduced | 4 (1.8%) | 0.74 | 0.71 |
| Note: Totals do not add to 100% due to rounding. | | | |

## Discussion

This project sought to understand the complex relationships among EHR adoption, EHR usability, work environments, and the outcomes of patients and healthcare providers in hospitals. Our work revealed that EHR adoption level and usability each play a significant role in outcomes, but that the work environment may play an important mediating role.

The findings from our first analysis suggest that adoption of a comprehensive EHR system is associated with greater nurse satisfaction with the system, more favorable reports of the system's usability, and higher nurse-reported quality of care. Independent of the EHR adoption level, however, we found that the work environment is also highly associated with nurses' ratings of EHR usability. When both EHR adoption level and work environment were considered simultaneously in fully adjusted models, we noted that— in most cases— the effect of EHR adoption level on usability and nurse-reported quality and safety outcomes was moderated and sometimes rendered insignificant after including the work environment. This moderation effect was especially notable for the outcome of poor/failing patient safety grade and suggests that the work environment may play a more important role in the delivery of safe patient care than the type of EHR system.

Our second analysis explored the simultaneous effects of EHR adoption level and usability on patient and clinician outcomes. Across all studied outcomes, EHR usability was a stronger predictor of outcomes than level of EHR adoption. Poor usability of EHR systems was associated with a significant increase in the odds of nurse burnout, job dissatisfaction and intentions to leave. These findings are aligned with the numerous emerging reports of physician burnout and EHRs [6,7] and document the presence of this relationship among nurses. Our

findings offer a novel explanation for the equivocal findings in the literature about the effects of EHR adoption on patient outcomes—differences in EHR system usability.

We observed null findings in our third analysis that examined changes in EHR adoption level and patient outcomes over time. Although results trended in the expected direction, (i.e. lower mortality rates in hospitals that went from no EHR to a comprehensive system), we did not observe statistically significant findings. The low mortality rates of general surgical patients overall and our inability to account for time that that EHR system had been in place significantly limited our analysis and ability to draw conclusions.

**Implications**

Our collective results suggest that EHR usability may be more important to patient outcomes and clinician wellbeing than the level of EHR adoption. Although our results do suggest that use of comprehensive EHR systems may be beneficial to quality of care, our work also suggests that burnout may be higher in hospitals with these more sophisticated systems. Our findings also revealed a strong relationship between the work environment and EHR usability. This suggests that hospitals with better work environments may be involving nurses in the selection and implementation of EHR systems. Nurse involvement in the development, selection, and modification of EHR systems should be a priority for EHR vendors and hospital administrators. Failing to involve nurses in these processes may have significant negative implications for nurses' health, workforce turnover and related costs, and patient outcomes. Future research on EHR effectiveness should incorporate measures of EHR usability in order to obtain a more complete understanding of how these systems affect clinicians' daily work and patient outcomes.

## 7. LIST OF PUBLICATIONS AND PRODUCTS

*Published Manuscripts*
Kutney-Lee A, Sloane DM, Bowles K, Burns LR, Aiken LH. Electronic health record adoption and nurse reports of usability and quality of care: The role of work environment. Appl Clin Inform. 2019; 10:129–139. doi: 10.1055/s-0039-1678551

*Manuscript Under Review*
Kutney-Lee A, Brooks Carthon JM, Sloane DM, Bowles KH, McHugh MD, Aiken LH. Association of electronic health record adoption and usability on nurse burnout and surgical patient outcomes.

*Conference abstracts*
Kutney-Lee A, McHugh MD, Brooks Carthon JM, Sloane DM, Bowles KH, Aiken LH. Usability of electronic health record systems in hospitals: Implications for nurse burnout. 2019 Jun. Podium presentation at AcademyHealth Annual Research Meeting, Washington, DC.

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