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The Effect of Hospital Electronic Health Record Adoption on Nurse-Assessed Quality of Care and Patient Safety

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Abstract

The aim of this study was to examine the effect of having a basic electronic health record (EHR) on nurse-assessed quality of care, including patient safety. Few large-scale studies have examined how adoption of EHRs may be associated with quality of care. A cross-sectional, secondary analysis of nurse and hospital survey data was conducted. The final sample included 16,352 nurses working in 316 hospitals in 4 states. Logistic regression models were used to evaluate the relationship between basic EHR adoption and nurse-assessed quality of care outcomes. Nurses working in hospitals with basic EHRs consistently reported that poor patient safety and other quality outcomes occurred less frequently than reported by nurses working in hospitals without an EHR. Our findings suggest that the implementation of a basic EHR may result in improved and more efficient nursing care, better care coordination, and patient safety.

The widespread adoption and “meaningful use” of electronic health records (EHRs) is a national priority. The potential for information systems to assist in addressing the overuse, underuse, and misuse of healthcare services has been long identified by the Institute of Medicine.^{1,2} Recent estimates report that only 12% of United States (US) hospitals have a basic EHR system in place, whereas fewer (2%) have a comprehensive EHR including decision support elements³—the most effective way to meet the most recent meaningful use criteria.⁴ Few large-scale studies have examined how adoption of EHRs may be associated with quality of care. Less is known about how nurses—arguably the primary end users of technology systems—perceive quality of care and patient safety in hospitals with implemented EHRs.

The evidence regarding the impact of EHRs on quality of patient care is undeniably mixed despite estimates that these technologies could save the US healthcare system more than 81 billion dollars a year.⁵ Strong evidence highlights the potential of computerized provider order entry (CPOE)—a component of a basic EHR—in reducing the incidence of medication errors.⁶ A study of over 3,000 hospitals by McCullough and colleagues⁷ found that a hospital’s use of an EHR, including CPOE, contributed to significantly better performance on some, but not all, of Medicare and Medicaid Services’ Hospital Compare process-quality measures. In studies of hospitals within single US states, certain elements of EHR systems have been associated with improved quality outcomes, including lower

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mortality and complication rates.^{8–10} An increasing body of evidence highlights the unintended and unanticipated consequences on quality of care after EHR introduction,^{11–13} including increased nursing staffing levels.¹⁴ Some studies have noted increased mortality,¹⁵ complications,¹⁴ and medication errors¹⁶ after EHR implementation, whereas others have shown outcomes to be equivocal.^{17,18}

A current systematic literature review on the impact of EHR systems on nursing care is generally positive.¹⁹ Overall EHRs are associated with reductions in medication administration errors and time spent on documentation, as well as improved quality of nursing documentation. Nurse communication and workflow seem to be positively influenced by technology as studies have identified nurse satisfaction with improved integration of technology systems into workflow processes, such as documentation, medication, and patient discharges and transfers.^{20,21} We found only 1 study that examined nurses' assessments of quality in hospitals that had adopted EHRs. DesRoches and colleagues²² conducted a national survey of more than 3,400 nurses in 2006 (approximately 1,000 of the respondents worked in hospitals) and found that nurses who worked in hospitals with at least a minimally functioning EHR were more likely than other nurses to report nursing excellence and quality improvement efforts in their workplace. Our study expands upon these findings and addresses more specific quality of care outcomes, including patient safety, from the perspective of more than 16,000 hospital staff nurses working in 4 large states in the US. The purpose of this study was to determine whether having a basic EHR was associated with patient safety and quality outcomes as assessed by nurses—the frontline providers of care.

Methods

Data Sources

This study was a cross-sectional, secondary analysis of 3 data sources: (1) the 2006 to 2007 multi-state nursing care and patient safety (MSNCPS) survey of nurses collected in 4 large states in the US,²³ (2) the 2008 American Hospital Association (AHA) EHR Adoption database,²⁴ and (3) 2007 AHA Annual Survey data.²⁵ The study was deemed exempt from review by the institutional review board of the University of Pennsylvania.

The MSNCPS survey data were collected by mail from large random samples of RNs in California, Florida, New Jersey, and Pennsylvania. More than 98,000 nurses completed the survey (35% response rate). A follow-up survey was sent to nonresponders to determine if response bias was an issue of concern. A 91% response rate was achieved on the follow-up survey and revealed no significant differences in how nurses rated their hospitals.²⁶ The survey included questions about workload and patient outcomes, including items from the Agency for Healthcare Research and Quality (AHRQ) patient safety culture survey. Nurses were asked to identify their employing hospital, and the AHA identification number was used to link the data sources. Staff nurses who worked in direct patient care were used for this analysis.

The 2008 AHA EHR Adoption database is a supplement to the AHA Annual Survey. The data provide information on hospitals' adoption of EHR components, including electronic clinical documentation (eg, medication lists, nursing notes), results viewing (eg, laboratories, radiology, CPOE), decision support (eg, clinical guidelines, drug alerts), and bar coding (eg, laboratories, medications). The data specify the degree to which these functions are implemented within the hospital, as well as future plans for implementation. The AHA annual survey was used to identify structural characteristics of hospitals such as teaching status, size, and technology status.

Measures

Basic EHR System—A hospital was identified as having a basic EHR system if it was reported on the AHA EHR Adoption survey that the following electronic features were implemented in all patient care units: (1) clinical documentation of the demographic characteristics of patients, problem lists, medication lists, and discharge summaries; (2) laboratory reports, radiologic reports, and diagnostic test results, and (3) CPOE for medications. This definition of a basic EHR system was based on the criteria used by Jha and colleagues²⁷ in their initial report on the use of EHR in US hospitals using the AHA EHR adoption data.

Nurse Staffing—Nurse staffing was used as a control variable in this study because more favorable nurse staffing is associated with better patient safety and quality outcomes.²⁸ Staffing was measured by nurses' survey responses about the number of patients they cared for on their last shift. Responses were aggregated to the hospital level, as nurse staffing was conceptualized as a hospital characteristic for this study. Nurses were included in the measure if they cared for at least 1 but not more than 20 patients.

Nurse-Assessed Quality of Care and Patient Safety Outcomes—Four items on the nurse survey were derived from the AHRQ patient safety culture survey. Nurses were asked to report levels of agreement with statements related to frequency of lost patient information during shift changes and patient transfers, as well as the priority placed on patient safety by hospital management. Responses for these 3 items were scored on a 5-point Likert-type scale from "strongly agree" to "strongly disagree." Nurses gave their unit an overall grade on patient safety (A, excellent; B, very good; C, acceptable; D, poor; or F, failing). Three additional outcome measures related to patient safety and quality of care were used in the study. Nurses were asked to provide the relative frequency of medication errors on a 7-point Likert-type scale from "never" to "every day." Medication errors were considered frequent if nurses reported that they occurred more than once a month. Nurses assigned a quality of care rating on 4-point Likert-type scale from "excellent" to "poor" and rated their confidence in patients' readiness for discharge on 4-point Likert-type scale from "very confident" to "not at all confident." All nurse-assessed patient outcomes were collapsed into dichotomous categories ("agree/disagree," "confident/not confident," etc) for the analysis to aid in the interpretation of the results. Previous work has shown that nurses are a reliable and valid source of data on adverse events and quality of care.^{29,30}

Structural Hospital Characteristics—Three structural hospital characteristics derived from the AHA annual survey were used as control variables as they are often associated with quality of care.³¹ Hospitals were classified into 3 sizes: small (≤ 100 beds), medium (101–250 beds), and large (>251 beds). Teaching status was classified into 3 categories based upon the ratio of postgraduate medical residents or fellows to beds: nonteaching, minor (1:4 ratio or smaller), and major (1:4 ratio or larger). Hospitals were classified as having high (vs low)-technology status if the hospital had facilities for open heart surgery and/or major organ transplantations.

Data Analysis

Hospitals were included in the final sample if they had a sufficient number of nurses to provide reliable estimates of staffing and outcomes and had responded to the AHA EHR Adoption survey and the AHA annual survey. The final analytic sample included 16,352 nurses working in 316 hospitals. Descriptive statistics were calculated to assess differences in EHR adoption by hospital characteristics and state. The nurse-assessed patient outcomes were examined descriptively and estimated separately for nurses who worked in hospitals with, and nurses who worked in hospitals without, fully implemented EHRs. At the nurse

level, robust logistic regression models that accounted for the clustering of nurses within hospitals were used to examine the effect of EHR adoption on outcomes before and after adjusting for nurse staffing and other hospital characteristics. Odds ratios and 95% confidence intervals were calculated. Analyses were conducted with SAS version 9.2, (SAS Institute, Inc, Cary, NC) and results were considered statistically significant at $P < .05$.

Results

Only 21 (7%) of the 316 hospitals in the sample had a basic EHR system implemented on all patient care units. Our sample was reflective of the EHR status of hospitals nationally—less than 10% of US hospitals had a fully implemented basic EHR²⁷ in 2008. There were no significant differences between hospitals with and without a basic EHR in terms of staffing levels, size, teaching status, and technology (Table 1).

Nurses in hospitals with fully implemented basic EHRs were consistently and significantly less likely to report unfavorable outcomes in their hospitals than did nurses in hospitals without fully implemented basic EHRs (Table 2). That is, lower percentages of nurses in hospitals with fully implemented basic EHRs indicated that poor outcomes occurred more frequently. For example, among the AHRQ patient safety culture items, 16.8% of nurses who worked in hospitals with a fully implemented basic EHR reported that the actions of hospital management did not highly prioritize patient safety, compared with 22.5% of nurses who worked in hospitals without a fully implemented basic EHR ($P < .001$). Fewer nurses working in hospitals with a fully implemented basic EHR also reported more frequent medication errors, fair/poor quality of care, and poor confidence in patients' readiness for discharge.

The results of the logistic regression models are displayed in Table 3. For 6 of the 7 outcomes studied, there was a significant bivariate relationship between adoption of a basic EHR and nurse-assessed outcomes. The second set of models included a control for nurse staffing levels. As expected, nurse staffing was a significant predictor of most of the studied outcomes, and although the effect was slightly moderated by staffing levels, the presence of a basic EHR system remained a strong and statistically significant predictor of 5 outcomes. In the fully adjusted models, a basic EHR was a significant predictor of 4 of the 7 outcomes. When compared with nurses working in hospitals without a fully implemented basic EHR, nurses working in hospitals with a fully implemented basic EHR had a 14% (ie, $(1 - 0.86) \times 100$) decrease in the odds of reporting that "things fell between the cracks" when transferring patients between units ($P < .05$), a 25% decrease in the odds of reporting that actions of hospital management show that patient safety is a low priority ($P = .001$), an 18% decrease in the odds of giving their unit a poor grade on patient safety ($P < .05$), and a 17% decrease in the odds of reporting that they were not confident in patients' readiness for discharge ($P < .05$).

Discussion

This is some of the first evidence using nurse assessments from a large sample of hospitals to show that implementation of a basic EHR may improve continuity of patient care and promote patient safety. Nurse reports of quality of patient care were compared in hospitals with and without a fully implemented basic EHR. Despite the small numbers of hospitals, we found several associations between the implementation of a basic EHR and better quality of care.

Although nurses in our survey did not comment on the impact of EHR systems specifically, we were able to measure nurses' assessments of the efficiency and quality of nursing in

hospitals in their respective institutions. Nurses working in hospitals with a basic EHR were less likely to report that things fell “between the cracks” when transferring patients between units, and they also were less likely to report that they were not confident in patients’ readiness for discharge. These findings suggest that the level of detail available in EHRs may allow for more comprehensive unit transfer reports, as well as discharge summaries to posthospitalization healthcare providers, in addition to verbal or written reports. Therefore, nursing administrators should be fully engaged in the process of EHR adoption and implementation to ensure effective use and success.¹⁹ It is important to note that having a basic EHR was associated with better outcomes independently of nurse staffing, indicating that they both play an important role in the quality of care. We did test interaction models between the presence of a basic EHR and nurse staffing; however, the interaction term was not significant, suggesting that the effect of having a basic EHR is not different for hospitals with varying staffing levels.

Our findings come at an opportune time as healthcare providers are being urged to adopt EHR systems. Beginning in January 2011, hospitals and other eligible healthcare providers were able to register for the Medicare and Medicaid EHR incentive programs.³² These programs were created by the Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009, with allotted funds from the American Recovery and Reinvestment Act (ARRA). Under HITECH, federal incentive payments are provided for individual healthcare providers and hospitals to adopt, implement, and demonstrate meaningful use of EHR technologies. The amount hospitals may receive is dependent upon a number of factors; however, base incentive payments begin at \$2,000,000. Part of HITECH also stipulates that healthcare providers and hospitals that receive payments from Medicare are required to demonstrate meaningful use of EHR technology by 2015 to avoid reductions in reimbursement payments.³²

Limitations

We note a few limitations to our study that were imposed by our data. There were a relatively small number of hospitals ($n = 21$) with fully implemented basic EHRs, making it difficult to detect effects and nearly impossible to reliably assess hospitals with comprehensive EHRs. Regardless of this limitation, statistically significant associations were found. Also, we may have underestimated hospital/nurse EHR users. Some hospitals may have had EHRs implemented on some units but not all. The AHA EHR adoption database only distinguishes “all” or “some” units with adoption. Because of the nature of our nurse survey, we could not examine unit-level associations. This study represents a very early demonstration of the potential effects of EHR implementation, not necessarily meaningful use as defined by the regulation.⁴ Response bias was noted in the collection of the AHA EHR data supplement, and higher quality hospitals may have participated.²⁷ Finally, we acknowledge that the dates of the nurse survey and AHA EHR supplement are not parallel; however, EHRs may take years to fully implement.⁵ Therefore, we assume that the nurse respondents working in hospitals with basic EHRs were actively using the technology at the time of the nurse survey.

Conclusion

Our findings suggest that the implementation of a basic EHR, including CPOE, shows promise in bringing about improved and more efficient nursing care, better care coordination, and safety for patients. With the passage of the HITECH Act, EHRs are rapidly becoming part of the daily practice of the bedside nurse. Nurse leaders hold an important position to emphasize the capability EHRs have in creating seamless transitions for patients throughout the care continuum to ensure appropriate user buy-in and rapid uptake. The degree to which nurse leaders support the growth of technology and champion

its use in the clinical setting is bound to affect the success of EHR implementation and, subsequently, patient care.

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Table 1

Distribution of Hospital Characteristics by Basic Electronic Health Record (EHR) Adoption

Characteristic	All (n = 316 Hospitals)	Basic EHR Fully Implemented (n = 21)	No EHR or Basic EHR Not Fully Implemented (n = 295)	<i>P</i> ^a
Staffing, patients per nurse, mean (SD)	5.1 (1.1)	4.8 (1.3)	5.1 (1.1)	.25
Bed size, n (%)				.11
≤100 beds	37 (12%)	0 (0%)	37 (13%)	
101–250 beds	134 (42%)	8 (38%)	126 (43%)	
>250 beds	145 (46%)	13 (62%)	132 (45%)	
Teaching status, n (%)				.24
None	165 (52%)	8 (38%)	157 (53%)	
Minor	118 (37%)	9 (43%)	109 (37%)	
Major	33 (10%)	4 (19%)	29 (10%)	
Technology status				.87
Low	175 (55%)	12 (57%)	163 (55%)	
High (performs open heart surgery and/or organ transplantations)	141 (45%)	9 (43%)	132 (45%)	
State				.38
California	108 (34%)	9 (43%)	99 (34%)	
Florida	83 (26%)	5 (24%)	78 (26%)	
New Jersey	37 (12%)	4 (19%)	33 (11%)	
Pennsylvania	88 (28%)	3 (14%)	85 (29%)	

^a*P* values generated from *t* test for staffing variable. *P* values generated from χ^2 for technology variable. Fisher exact test used for bed size, teaching status, and state variables for cell counts <5. Percentages may not add to 100 because of rounding.

Table 2

Nurse-Assessed Quality of Care and Patient Safety Outcomes in Hospitals by Basic Electronic Health Record (EHR) Adoption

Outcomes	All (n = 16,352 Nurses)	n (%) of Nurses Agreeing With Statement Who Work in Hospitals With:		<i>p</i> ^a
		Fully Implemented Basic EHR (n = 1,621)	No EHR or Basic EHR Not Fully Implemented (n = 14,731)	
Important patient information is frequently lost at shift changes	4825 (29.5%)	440 (27.1%)	4385 (29.8%)	.03
Things fall between the cracks when transferring patients from 1 unit to another	5667 (34.7%)	502 (31.0%)	5165 (35.1%)	.001
Actions of hospital management show patient safety is not a top priority	3592 (22.0%)	273 (16.8%)	3319 (22.5%)	<.001
Poor overall unit grade on patient safety	4996 (31.4%)	423 (26.9%)	4573 (31.9%)	<.001
Medication errors occur frequently	696 (4.5%)	49 (3.2%)	647 (4.7%)	.01
Quality of care on your unit is fair or poor	2421 (15.5%)	187 (12.1%)	2234 (15.9%)	<.001
Not confident in patients' readiness for discharge	6676 (40.8%)	582 (35.9%)	6094 (41.4%)	<.001

^a*P* values generated from χ^2 . Percentages may differ because of missing data. Sample size for "poor overall unit grade on patient safety" = 15,902. Sample size for "medication errors occur frequently" = 15,449. Sample size for "quality of care on unit is fair/poor" = 15,626.

Table 3

Odds Ratios (ORs) Indicating the Effects of a Basic Electronic Health Record (EHR) on Nurse-Assessed Quality of Care and Patient Safety (n = 16,352 Nurses)

Outcome	Unadjusted Model		Adjusted for Nurse Staffing		Fully Adjusted Model	
	OR	(95% Confidence Interval [CI])	OR	(95% CI)	OR	(95% CI)
Patient information is frequently lost at shift change						
Basic EHR	0.88	(0.76–1.01) ^a	0.90	(0.77–1.05)	0.92	(0.81–1.05)
Nurse staffing			1.06	(1.01–1.11) ^b	1.11	(1.04–1.18) ^c
Things fall “between the cracks”, when transferring patients from one unit to another						
Basic EHR	0.83	(0.70–0.98) ^b	0.84	(0.71–0.99) ^b	0.86	(0.75–0.99) ^b
Nurse staffing			1.03	(0.97–1.08)	1.10	(1.03–1.17) ^d
Actions of hospital management show patient safety is a low priority						
Basic EHR	0.70	(0.58–0.84) ^c	0.71	(0.59–0.86) ^c	0.75	(0.63–0.89) ^c
Nurse staffing			1.07	(1.01–1.14) ^b	1.12	(1.04–1.21) ^d
Poor overall unit grade on patient safety (C, D, or E)						
Basic EHR	0.78	(0.67–0.92) ^d	0.81	(0.69–0.95) ^d	0.82	(0.70–0.96) ^b
Nurse staffing			1.12	(1.06–1.18) ^c	1.16	(1.09–1.24) ^c
Frequent medication errors						
Basic EHR	0.68	(0.48–0.96) ^b	0.70	(0.49–0.99) ^b	0.74	(0.53–1.03) ^a
Nurse staffing			1.07	(0.96–1.19)	1.14	(1.02–1.28) ^b
Quality of care on your unit is fair or poor						
Basic EHR	0.73	(0.57–0.94) ^b	0.78	(0.60–1.01) ^b	0.79	(0.62–1.01) ^a
Nurse staffing			1.23	(1.14–1.32) ^c	1.32	(1.20–1.45) ^c
Not confident in patients’ readiness for discharge						
Basic EHR	0.79	(0.68–0.92) ^d	0.82	(0.70–0.95) ^d	0.83	(0.71–0.96) ^b
Nurse staffing			1.09	(1.03–1.15) ^d	1.14	(1.07–1.21) ^c

Notes:

^a P < .10;

^b P ≤ .05;

^c $P \leq .001$;

^d $P \leq .01$.

ORs are from robust logistic regression models adjusted for nurse (sex, experience, education, and nursing specialty) and hospital (size, teaching status, technology, state) characteristics and the clustering of nurses within hospitals. Sample size for “poor overall unit grade on patient safety” = 15,902. Sample size for “medication errors occur frequently” = 15,449. Sample size for “quality of care on unit is fair/poor” = 15,626.