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EHR Adoption and Cost of Care – Evidence from Patient Safety Indicators

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Abstract

Aim: The adoption and implementation of Electronic Health Records (EHR) have the potential to reduce cost of care. Empirical evidence on the relationship between EHR adoption and cost reduction in hospital inpatient care, especially in patient safety related services, has been sparse and inconclusive. This study examined the relationship between the level of electronic health records (EHRs) implementation and cost of care in related to patient safety indicators.

Methods: Study was cross-sectional. Data were extracted from the 2009 National Inpatient Sample and the 2009 American Hospital Association (AHA) electronic health record implementation survey. Final sample was 2,626,743 discharges from acute care hospitals in the United States. The mixed model regression was used to analyze three levels of EHR implementation and costs related to eleven patient safety indicators.

Results: Hospitals with a comprehensive EHR system had marginally significant lower cost per discharge for three patient safety indicators compared to hospitals with no EHR system. Compared to hospitals with no EHR, costs were $4,246 lower for Postoperative hemorrhage or hematoma, $4,205 lower for postoperative pulmonary embolism or deep vein thrombosis, and $4,971 for postoperative wound dehiscence among hospitals with a comprehensive EHR. Costs among hospitals with a basic EHR were not significantly different than those with no EHR.
Conclusions: The high level of EHR implementation was moderately associated with low cost of care.

Keywords: electronic health records, patient safety indicator, cost of care, health information technology

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The Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009 promotes the adoption and meaningful use of health information technology (HIT) through financial incentives. As a result, HIT has become a major area of focus in the health care industry.[1] The adoption and implementation of HIT such as Electronic Health Records (EHR), Electronic Medical Records (EMR), Computerized Physician Order Entry (CPOE), and Clinical Decision Support Systems (CDSS) have the potential to reduce costs in the long-term.[2] Among these HIT strategies, EHR has been one of the most widely adopted by health care organizations including hospitals. The Office of the National Coordinator for Health Information Technology (ONC) reports that implementation of EHR among hospitals increased close to 50 percent from 2009 to 2013.[3]

Empirical evidence on the relationship between EHR adoption and cost reduction in hospital inpatient care, especially in patient safety related services, has been relatively sparse and inconclusive.[4] Connelly and colleagues found that use of EHR resulted in fewer hospitalizations, laboratory tests, and medications for heart failure patients in two of three emergency departments.[5] Zlabek and colleagues observed reduced costs from lab tests, radiology examinations, monthly transcriptions, and medication error incidents in an inpatient care section of a hospital.[6] Amarasingham and colleagues studied 41 hospitals in Texas using the Clinical Information Technology Assessment Tool to measure a hospital's level of automation based on physician interactions with the information system and found that higher scores on test results, order entry, and decision support were associated with lower costs.[7] However, Himmelstein and colleagues,[8] based on an annual survey of computerization at approximately 4,000 hospitals for the period from 2003 to 2007, reported that hospital computing did not reduce administrative or overall costs.

Furthermore, despite the potential benefits of EHR adoption in terms of cost reduction, hospitals are still lagging in the adoption of EHR and other HIT. While the implementation of at least a basic EHR system increased from 12 percent in 2009 to 59 percent in 2013, over 40 percent of hospitals remain without a basic system,[9] This may be partially explained by the significant commitment of resources and organizational modifications/restructuring associated with hospitals implementing EHR. Financial, time, and workforce constraints have been found to be barriers to EHR adoption.[10]

As all major stakeholders in the health care industry are exploring cost-containment strategies, further research is needed to explore the relationship between the use of EHR and cost of hospital inpatient care. The EHR systems facilitate patient safety through the use of checklists, alerts, and predictive tools; embedded clinical guidelines that promote standardized, evidence-based practices; electronic prescribing and test-ordering that may reduce errors and redundancy; and discrete data fields that foster use of performance dashboards and compliance reports. It can also improve efficiency including cost reduction through faster, more accurate communication and streamlined processes, improved patient flow, fewer duplicative tests, faster response to patient inquiries, and redeployment of transcription and claims staff. Furthermore, EHR systems may enhance revenues through more complete capture of charges, and federal incentive payments.[11] The purpose of this study is to explore the relationship between EHR adoption and

cost of patient safety. Our study attempts to address some of the gaps of previous research on the relationship between EHR and hospital inpatient costs. First, our study is focused on the relationship between EHR and the cost of patient safety in hospitals. Further, we use a more comprehensive measure of EHR adoption, which consists of a three-level EHR adoption measure: comprehensive, basic, and no EHR. Previous studies on EHR and patient safety have oftentimes used a two-level measure ("yes or no") to measure EHR adoption.[12]

Our general hypothesis is as follows:

H1: Patients treated at hospitals with a higher level of EHR adoption are more likely to incur lower costs for treating their patient safety related conditions.

Methods

Study Design and Data: This was a cross-sectional study and the unit of the analysis was hospital discharge. The data used were obtained from three sources: 2009 National Inpatient Sample (NIS), 2009 American Hospital Association (AHA) Annual Survey Information Technology (IT) Supplement, and the 2009 Agency for Healthcare Research and Quality (AHRQ) Cost-to-Charge Ratio (CCR) file. The NIS is a nationally representative sample of community hospitals, comprising about 20% of US hospital discharges. We focused on discharges from acute care, short- stay general hospitals. Of the 1,050 hospitals included in the NIS dataset, only 595 had AHA identification available because some states block hospital information when providing hospital discharge data to AHRQ. The 2009 AHA Annual Survey IT Supplement includes data on 2,578 acute short-term general hospitals. The AHRQ's CCR file enables conversion from hospital charges to cost. The file contains hospital-specific cost-to-charge ratios based on all-payer inpatient cost for nearly every hospital in the NIS. Cost information was obtained from the hospital accounting reports collected by the Centers for Medicare and Medicaid Services (CMS). CMS conducted some imputations for missing values while calculating costs and cost-to-charge ratios for each hospital. The NIS and CCR files are part of AHRQ's Healthcare Cost and Utilization Project (HCUP).

After merging the NIS, AHA IT Supplement, and CCR datasets, 366 hospitals remained. The number of discharges included in the analysis was 2,626,743 in the 366 hospitals, identified by running the AHRQ Patient Safety Indicator (PSI) Software, Version 4.4.[13] Main characteristics of the hospitals retained for analysis and hospitals excluded due to missing AHA ID are listed in Appendix 1. It appears that the retained hospitals were larger in regard to the number of beds. They had higher percentages of publically owned or not for profit but a lower percentage of investor-owned, higher percentages of system affiliation and having capitation-based reimbursement, and were located in more concentrated market areas.

Measures: Our dependent variables were 11 costs of care per discharge that corresponded to 11 patient safety indicators (Figure 1), developed by AHRQ.[14] After running the AHRQ PSI software on the 2009 NIS data, we identified 17 patient safety indicators. We dropped six indicators whose frequencies were less than 0.1% because meaningful differences in those indicators across different levels of EHR adoption may not be detected by very low frequencies. Those six indicators were death in low-mortality diagnosis related groups (DRGs) (frequency = 0.03%), retained surgical item or unretrieved device fragment (this is a count measure and there

were only 238 discharges in the 2009 NIS), iatrogenic pneumothorax (frequency = 0.05%), central venous catheter-related blood stream infection (frequency = 0.05%), postoperative hip fracture (frequency = 0.01%), and transfusion reaction (this is a count measure and there were 15 discharges in the 2009 NIS). Definitions and frequencies of the retained 11 indicators in this study are listed in Figure 1.

Figure 1: Dependent and Independent Variable Definitions and Data Sources

Variable	Definition	# of Discharges*	Frequency
Dependent variable			
PSI 03 cost	Estimated cost of treating PSI03, In-Hospital Pressure Ulcer, conditions	576,523	0.52%
PSI 04 cost	Estimated cost of treating PSI04, Death Among Surgeries, conditions	20,301	0.28%
PSI 09 cost	Estimated cost of treating PSI09, Post Operative Hemorrhage or Hematoma, conditions	563,532	12.37%
PSI 10 cost	Estimated cost of treating PSI10, Post Operative Physiometabolic Derangement, conditions	254,050	0.13%
PSI 11 cost	Estimated cost of treating PSI11, Post Operative Respiratory Failure, conditions	204,883	0.93%
PSI 12 cost	Estimated cost of treating PSI12, Post Operative PE or DVT, conditions	563,953	1.10%
PSI 13 cost	Estimated cost of treating PSI13, Post Operative Sepsis, conditions	50,477	1.54%
PSI 14 cost	Estimated cost of treating PSI14, Postoperative Wound Dehiscence, conditions	88,920	0.20%
PSI 15 cost	Estimated cost of treating PSI15, Accidental Puncture/Laceration, conditions	1,858,881	0.28%
PSI 18 cost	Estimated cost of treating PSI18, In-Hospital OB (obstetrical) Trauma-Vaginal with Instrument, conditions	14,290	16.00%
PSI 19 cost	Estimated cost of treating PSI19, OB Trauma-Vaginal without Instrument, conditions	173,911	2.28%

PSI: patient safety indicator

PE or DVT: Perioperative Pulmonary Embolism or Deep Vein Thrombosis

* The AHRQ Patient Safety Indicator software generated a sub-set of the discharges in NIS for each of the patient safety indicator, respectively.

The 2009 NIS contain data on total charges for each hospital in the dataset. This charge information represents the amount that hospitals billed for services, but does not reflect how much hospital services actually cost or the specific amounts that hospitals received in payment. As a result, hospital costs for each of 11 patient safety indicators was obtained by multiplying total charges with the cost-to-charge ratio.[15]

Our main independent variable consists of a categorical variable denoting the three levels of hospital EHR adoption developed by Jha and colleagues.[16] The definitions of the three levels are shown in Figure 2. The highest level, "EHR_comprehensive", represents hospitals that have implemented a comprehensive EHR system. The middle level, "EHR_basic", represents hospitals that have implemented a basic EHR system. The lowest level represents hospitals not maintaining at least a basic level of EHR system and served as the reference group. We adopted this approach over the Health Information Management Systems Society (HIMSS) approach because it is more detailed and comprehensive. Also, it measures three levels of adoption while the HIMSS measure of EHR adoption only captures two levels.

Figure 2. Definitions of Levels of EHR Implementation at Hospital*

Requirement	Comprehensive EHR System	Basic EHR System
Clinical documentation		
Demographic characteristics of patients	X	X
Physicians' notes	X	
Nursing assessments	X	
Problem lists	X	X
Medication lists	X	X
Discharge summaries	X	X
Advanced directives	X	
Test and imaging results		
Laboratory reports	X	X
Radiologic reports	X	X
Radiologic images	X	
Diagnostic-test results	X	X
Diagnostic-test images	X	
Consultant reports	X	
Computerized provider-order entry		
Laboratory tests	X	
Radiologic tests	X	
Medications	X	X
Consultant requests	X	
Nursing orders	X	
Decision support		
Clinical guidelines	X	
Clinical reminders	X	
Drug-allergy alerts	X	
Drug-drug interaction alerts	X	
Drug-laboratory interaction alerts	X	
Drug-dose support	X	

* A comprehensive EHR system was defined as a system with electronic functionalities in all clinical units. A basic EHR system was defined as a system with electronic functionalities in at least one clinical unit.

Source: Jha et al. "Use of Electronic Health Records in U.S. Hospitals." New England Journal of Medicine; 2009, 360(16):1628-1638.

In addition to the independent variable, we also controlled for other variables in the multivariable analysis. At the patient level, we controlled for patient's age, race/ethnicity (White (reference), African American, Hispanic/Latino, Asian, and other race/ethnicity), primary health insurance coverage (Medicare (reference), Medicaid, private insurance, uninsured, and other insurance).[17] We also controlled for patient severity of illness by using the AHRQ's list of 29 comorbidities.[18] At the hospital level, we included control variables related to structure, operations, and competitive factors. To measure hospital structure, we used the AHA bed size level (6-24 beds, 25-49 beds, 50-99 beds, 100-199 beds, 200-299 beds, 300-399 beds, 400-499 beds, and 500 or more beds), ownership type (public, not-for-profit (reference), and for-profit), teaching hospital (yes or no), system membership (yes or no), and network participation (yes or no). To measure hospital operations, we used full time equivalent nurses per adjusted patient days, and average daily census per staffed bed. To measure hospital environmental factors, we used percentage Medicare patients, percentage Medicaid patients, having capitation-based reimbursement (yes or no), Herfindahl-Hirschman index (HHI) (being calculated based on the hospital's total adjusted admissions), and hospital region (East, Midwest, South, and West (reference)). These hospital-level control variables were chosen given the role of these factors on patient costs.[19]

Data Analysis: To model the continuous cost dependent variables, we used the general linear mixed model for data analysis. The random effect was the intercept of each hospital and the fixed effects included the level of EHR adoption, patient sociodemographics, comorbidities, and hospital level variables. Due to the skewness of the cost data, we performed a logarithm transformation of the cost data before data analysis. The results obtained from the original data and from the transformed data were consistent and, thus, for the sake of easy interpretation, we only report the results of the original (non-logarithm transformed) cost data.

Results

Descriptive results of patients' sociodemographic and hospitalization characteristics are shown in Figure 3. Hospitals with a comprehensive EHR system have relatively lower percentages of patients covered by Medicaid and uninsured, but a relatively higher percentage of patients covered by private insurance. Patients in hospitals with a comprehensive EHR system incur the lowest average total charges per discharge ($32,958) among the three adoption levels, but the highest average cost per discharge ($13,015). Patients across the three levels of EHR adoption have similar average lengths of hospital stay and in-hospital mortality rates.

Figure 3. Patient Sociodemographic and Hospitalization Characteristics by Level of EHR Adoption

Variable	Comprehensive EHR (n = 165,499)	Basic EHR (n = 686,631)	Non-Adoption (n = 1,774,613)	p-Value
Sociodemographics				
Age	61.0(18.5)	60.9(19.0)	62.5(18.6)	***
Gender, %				***
- Male	47.4	47.9	46.07	
-Female	52.9	52.1	53.92	
Race/Ethnicity, %				***
- White	59.5	58.8	65.7	
-Black	13.0	12.1	10.3	
-Hispanic	2.6	7.6	8.8	
-Asian	2.9	2.6	2.1	
- Other	1.9	6.7	2.3	
- Unknown	20.2	12.3	10.9	
Primary Insurance, %				***
- Medicare	48.5	48.0	52.8	
- Medicaid	8.5	14.0	10.1	
- Private insurance	35.2	26.3	28.4	
- Uninsured	4.3	8.3	5.5	
- Other	3.5	3.4	3.2	
Hospitalization Characteristics				
Length of stay, day	4.8 (5.9)	5.2 (7.7)	4.9 (6.1)	***
Total charge, $	32,958 (46,501)	33,480 (50,785)	37,180 (56,016)	***
Cost, $	13,015 (18,679)	11,996 (17,825)	12,589 (17,021)	***
Died in hospital, %	3.4	3.2	3.3	**

Data are expressed as mean (standard deviation) unless otherwise indicated.

** $p < 0.05$, *** $p < 0.01$

Descriptive results for the hospital characteristics across the levels of EHR adoption are displayed in Figure 4. Hospitals with comprehensive EHR systems were more likely to be a teaching hospital or affiliated with a system; but less likely to be in a network and to have patients covered by Medicare or Medicaid.

Figure 4. Hospital Characteristics by Level of EHR Adoption

Variable	Comprehensive EHR (n = 19)	Basic EHR (n = 76)	Non-Adoption (n = 270)	p-Value
Hospital structure				
Number of staffed beds	207 (182)	246 (192)	187 (210)	
Ownership, %				
- Public	5.3	23.7	17.8	
- Not for profit	89.4	68.4	73.7	
- Investor owned	5.3	7.9	8.5	
Teaching hospital, %	31.6	32.9	17.8	***
Hospital operation				
Affiliated to a system, %	80.0	61.8	50.0	**
In a network, %	25	43.4	31.1	**
FTE nurses per 1,000 adjusted patient days	4.15 (1.86)	3.53 (1.60)	3.14 (1.58)	
Hospital environment				
Medicare discharges as % of total discharges	43.1 (11.6)	46.8 (43.3)	55.3 (69.0)	**
Medicaid discharges as % of total discharges	16.2 (7.7)	21.1 (21.4)	18.3 (32.1)	**
Having capitation-based reimbursement, %	10.0	23.7	14.1	
HHI	0.592 (0.395)	0.530 (0.454)	0.544 (0.418)	
Region, %				
- East	10.5	22.4	23.0	
- Midwest	42.1	26.3	27.0	
- South	26.3	25.0	26.3	
- West	21.1	26.3	23.7	

Data are expressed as mean (standard deviation) unless otherwise indicated.

** $p < 0.05$, *** $p < 0.01$

Results of the mixed model analysis on cost across three levels of EHR adoption are listed in Figure 5. Our hypothesis was moderately supported. Hospitals with a comprehensive EHR system had marginally significant lower cost per discharge for three patient safety indicators compared to hospitals with no EHR system. Compared to hospitals with no EHR, costs were $4,246 lower for Postoperative hemorrhage or hematoma, $4,205 lower for postoperative pulmonary embolism or deep vein thrombosis, and $4,971 for postoperative wound dehiscence among hospitals with a comprehensive EHR. Costs among hospitals with a basic EHR were not significantly different than those with no EHR, except for vaginal without instrument where costs were approximately $4,700 higher for hospitals with a basic EHR.

Figure 5. Mixed Model Regression Results of the Relationship between Level of EHR Adoption and Cost of Care per Discharge

Variable	Intercept[1]	Comprehensive EHR System[2]		Basic EHR System[2]	
		Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Pressure ulcer	$18,294	-$3,816	$2,626	-$1,199	$1,364
Death among surgery patients	$34,126	-$7,809	$5,989	-$1,546	$3,093
Postoperative hemorrhage or hematoma	$12,106	-$4,246*	$2,568	-$1,078	$1,305
Postoperative physiological metabolic derangement	$15,334	-$521	$2,053	$149	$1,053
Postoperative respiratory failure	$16,647	-$364	$1,967	$226	$1,006
Postoperative pulmonary embolism or deep vein thrombosis	$12,217	-$4,205*	$2,537	-$1,095	$1,289
Postoperative sepsis	$22,692	-$886	$3,025	$942	$1,574
Postoperative wound dehiscence	$15,660	-$,4971*	$2,849	-$1,068	$1,466
Accidental puncture/laceration	$7,448	-$2,200	$1,467	-$567	$764
OB trauma- Vaginal with instrument	$5,860	-$288	$760	-$223	$337
OB trauma- Vaginal without instrument	$3,235	-$2,248	$6,431	$4,671*	$2,816

* p < 0.10, ** p < 0.05, *** p < 0.01
OB: Obstetrics
Controlled for patient sociodemographics, comorbidities, bed size, ownership, having capitation-based reimbursement, number of beds per RN, system affiliation, network affiliation, and regional location.
[1] Cost of care per discharge for patients in hospitals with No EHR System;
[2] Reference Group - No EHR System

For most of the 11 patient safety indicators, associations between the level of EHR adoption and cost of care, more or less, tended to be monotonic, which means, although most were not statistically significant, patients in hospitals with a comprehensive EHR system had a lower average cost as compared to patients in hospitals with a basic EHR system, while patients in hospitals with a basic EHR system had a lower average cost as compared to patients in hospitals without an EHR system. For example, for death among surgery patients, the average cost for patients in hospitals with No EHR System was $34,126, whereas costs were $1,546 and $7,809 lower for patients in hospitals with a Basic EHR System and a Comprehensive EHR System, respectively (Figure 5).

Discussion

Health care reform is promoting the use of value creation strategies that may increase quality while lowering costs. It is widely recognized that EHR adoption has this potential for improving the quality, efficiency, and patient centeredness of care.[20] The Health Information Technology for Economic and Clinical Health Act, as a provision of the 2009 American Recovery and Reinvestment Act, outlined a multifaceted approach to improving healthcare quality and efficiency by encouraging healthcare providers to use EHRs. The ultimate goal of HITECH is not for hospitals to merely install EHR systems, but to incentivize them to become "meaningful users" of EHRs, which leads to improved quality and efficiency of care.[21]

This study shows some early evidence that a higher level of EHR adoption is moderately associated with lower cost of care in regard to patient safety indicators. While hospitals with a basic EHR system did not differ from those with no EHR with respect to costs, those with a comprehensive EHR system demonstrated moderately lower costs for several postoperative patient safety indicators. Our findings are consistent with existing literature. Research indicates that the use of EHR leads to increases in operational efficiency including streamlining processes, electronic prescribing, and more accurate communication techniques.[22] Perhaps one of the main reasons that the adoption of EHR may decrease cost of care is the reductions in duplication and use of resources.[23] EHR adoption may also improve hospitals' effectiveness by identifying risk factors, and facilitating the provision of treatment strategies and surveillance programs (Paxton EW et al, 2012).[24] For example, EHR use has been associated with a reduction in medication errors, which can prevent secondary harm to patients and improve patient outcomes.[25]

EHR carries potential to enhance quality and cost care but a relatively small proportion of hospitals in our sample had adopted EHR systems, particularly a comprehensive system. This is consistent with data from the Office of the National Coordinator for Health Information Technology showing that compared to other health care providers, hospitals lag in the implementation of EHR.[26] Our study found that the number of hospital beds, teaching hospital status, system affiliation, and the number of full-time RNs per adjusted patient days are positively associated with EHR adoption, which indicates that hospitals with slack resources tend to adopt EHR earlier than other hospitals. On the other hand, hospitals with relatively high percentages of patients covered by Medicare and Medicaid, which often have lower reimbursement rates than do private insurance plans, tend to be late EHR adopters. This is also consistent with literature that organizational infrastructure and financial resources constrain hospitals' EHR adoption.[27]

The study had some limitations. First, there were a relatively small number of hospitals that had either a comprehensive EHR system (19 hospitals) or a basic EHR system (76 hospitals). This may explain the lack of statistically significant differences in costs across the three levels of EHR adoption. Second, information about when a comprehensive or a basic EHR system was adopted was not available in the AHA EHR supplementary survey, so it is not clear whether the association between the level of EHR adoption and reduction in cost of care is short-term or long-term, or can be sustained. Third, over a half of hospitals were lost due to the merging of different datasets and availability of some data elements in the NIS dataset, which may limit the generalizability of our findings. Fourth, this study used 2009 data. Under the national push for the meaningful use of health information technology, it is expected that much more hospitals may have adopted an EHR in the last few years and more research is merited to examine more recent data in regard to patient safety and associated cost of care.

In conclusion, our study has shown preliminary but promising results that hospitals adopting a comprehensive EHR system may experience moderate patient cost reductions, particularly related to patient safety care. Further research is merited to investigate the longitudinal effect of EHR adoption, using datasets with more hospitals with EHR adoption, and targeting a broader clinical spectrum. Although barriers for adopting EHR exist and relatively few hospitals have adopted an EHR system, especially a comprehensive EHR system, the

financial incentives associated with meaningful use of information technology effective 2015 are likely to motivate hospitals to speed up the EHR adoption. Policy and programs to strengthen organizational infrastructure and financial resources are likely to assist hospitals in attaining the goals and objectives of meaningful use of EHR.

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Appendix 1. Characteristics of Included and Excluded Hospitals

Variable	Hospitals Included (n = 345)	Hospitals Excluded (n = 705)	p-Value
Number of staffed beds, mean (SD)	345 (199)	247 (152)	***
Ownership, %			***
- Public	19.4	13.4	
- Not for profit	72.5	56.3	
- Investor owned	8.1	30.4	
Affiliated to a system, %	53.6	45.9	**
In a network, %	28.3	32.8	
Having capitation-based reimbursement, %	16.2	8.5	***
Herfindahl-Hirschman Index (HHI), mean (SD)	0.6 (0.4)	0.4 (0.4)	***

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$