Association of Electronic Health Records With Cost Savings in a National Sample

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ABSTRACT

Objectives

To determine whether advanced electronic health record (EHR) use in hospitals is associated with lower cost of providing inpatient care.

Study Design

National Inpatient Sample (NIS) and the Health Information Management Systems Society (HIMSS) Annual Survey are combined in the restrospective, cross-sectional analysis. We study patients who are 18 years or older and discharged from a general acute care hospital.

Methods

Using 2009 data and a cross-sectional design with a gamma distributed generalized linear model, a patient-level analysis is conducted with propensity scores to control for selection bias. Patient- and organizational-level variables are included as controls. The main outcome measure is total cost per patient admission and represents the amount that it costs the hospital to provide services based on the adjusted charges for an admission.

Results

We include 5,047,089 individuals treated at 550 hospitals in the United States and represent a population-based sample. There are 104 (18.9%) hospitals included that use advanced EHRs. Patients treated in hospitals with advanced EHRs cost, on average, $731, or 9.66%, less than patients admitted to hospitals without advanced EHRs, after controlling for patient and hospital characteristics.

Conclusions

Hospitals that use advanced EHRs have lower cost per patient admission than comparable hospitals with similar case mix.

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Electronic health records (EHRs) have been suggested as a tool for improving the overall quality and cost of care in the United States.[1] Proponents and policy makers have created incentives through the Health Information Technology for Clinical and Economic Health (HITECH) Act to offset the cost of purchase in order to encourage the adoption and use of advanced EHR systems in a "meaningful" way.[2] Such criteria for use are based on previous studies that report improvements in quality.[3] To qualify as a meaningful user and benefit from the related incentives, EHR systems must include electronic prescribing, health information exchange with other providers, automated reporting of quality data, electronic recording of patients' history (demographics, vital signs, medication and diagnosis lists, and smoking status), created care summary documents, and at least 1 clinical decision support tool.[4-6] Such meaningful use requirements are believed to improve the legibility of records, reduce prescription errors, improve adherence to best clinical practice guidelines, improve patient and clinician access to records, and allow exchange of health information.[4] In addition to gains in quality, EHRs have been predicted to save $81 billion annually through safety improvement and increased efficiency of care,[7] yet little is known about their impact on hospital cost, and no previous studies have examined the relationship between cost per admission and EHR use in a national sample of acute care hospitals for adults.

Cost savings associated with EHRs are expected to come through better coordination of care, reduction of medical errors and adverse drug events (ADEs), and increased efficiency and reduction of duplicate testing; previous studies have demonstrated the potential. Silow-Carroll and colleagues found that at 9 hospitals with comprehensive EHR use, "Faster, more accurate communication and streamlined processes have led to improved patient flow, fewer duplicative tests, faster responses to patient inquiries, redeployment of transcription and claims staff, more complete capture of charges, and federal incentive payments," which lead to cost

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Take-Away Points

Advanced EHR use in hospitals has the potential to save money on patient care.

- This study supports the case for advanced EHR adoption and use, consistent with meaningful use.
- Advanced EHR use requires costly investment for hospitals that can be regained through savings in patient care.
- Patients treated in hospitals with advanced EHRs cost 9.66% less than those treated in hospitals without advanced EHRs.

savings.[8] Amarasingham and colleagues report that specific EHR components, including automated notes and records, order entry, and clinical decision support, are associated with fewer complications, lower mortality rates, and lower costs in Texas hospitals.[9] In a single hospital, inpatient EHR with computerized provider order entry (CPOE) use was associated with a decrease in laboratory tests, radiology examinations, monthly transcription costs, medication errors, and paper costs.[10] On the other hand, a study performed in California revealed that EHR use was associated with an increase in hospital costs, nursing staff levels, and complications, but a decrease in mortality for some conditions.[11] This same study did not find any evidence that advanced EHR use reduced length of stay or demand for nurses. Similarly, another study examining EHR use in physician practices found that electronic access to patient lab and imaging results may actually increase the number of overall tests given to individual patients by 40% to 70%, thus *increasing* costs.[12] In a study of Medicare patient–level billing data from 1998 to 2005, Agha reported that EHR adoption was associated with an initial 1.3% increase in billed charges, and saw no evidence of cost savings over the 5 years postadoption.[13]

In a previous study of a single hospital, physician inpatient order writing on microcomputers was found to be associated with reduced resource utilization.[14] These costs of providing care were approximately 12% lower in the area of overall charges, hospital charges, bed charges, diagnostic test charges, and drug charges, although the system required increased physician time. Similarly, the cost savings of advanced EHR use found in this study may be the result of several practices or benefits associated with advanced EHR use. First, the automated nature of advanced EHRs may reduce errors through overall coordination of care, less duplication of tests, and increased efficiency.

Dranove and colleagues examined the implementation of EHR as a business process innovation.[15] They used data from Medicare cost reports combined with survey data on EHR adoption to assess the economic implications of EHR adoption on mean cost per admission. They reported that EHR adoption was associated with a rise in cost, but that cost reduction for hospitals in favorable locations—where there was high availability of expertise and complementary services—resulted in cost reductions after 3 years, while hospitals with unfavorable conditions had increased costs, even after 6 years.

The objective of this study was to determine if advanced EHR use is associated with lower cost of care in acute care general hospitals. In an era of increased pressure to adopt EHRs and other health information technology, it is important to understand the benefits and challenges of EHR use. Our study adds to the work by Agha and Dranove by using more recent individual-level patient data that includes all payers.[13,15] Our cost measure reflects the variation in cost per admission observed at the level of the individual, as opposed to the mean for the hospital, which allowed us to control for variations in case mix. We limited our analysis to contrasting hospitals with advanced EHRs to all other levels of implementation based on the finding by Dranove and colleagues that cost savings due to EHR implementation are most likely observed for institutions with a critical mass of EHR expertise.

METHODS

The data for this cross-sectional patient-level analysis were obtained from the National Inpatient Sample (NIS) 2009 and Health Information Management Systems Society (HIMSS) 2009. The NIS includes discharge data from more than 1000 hospitals in 45 states, which encompasses 96% of the United States population. The HIMSS 2009 data were used to measure hospital EHR use. The HIMSS data "represent a broad canvassing of acute care hospitals, chronic care facilities, ambulatory practices on their adoption and plans to adopt various HIT components" and have been widely used in previous research.[16]

Patients were included in the analysis if they were 18 years or older. In the NIS, some states do not release the American Hospital Association identifiers, and thus the individual patient cases cannot be included because EHR use cannot be determined. Costs were calculated for each admission using the total charges reported multiplied by the hospital-specific cost-to-charge ratio for 2009. Admissions with zero charges were excluded from the analysis.

The generalized linear model and propensity models controlled for patient age, gender, race, All Patient Refined Diagnosis Related Groups (APDRGs) mortality and

severity, neonatal or maternal status, private insurance coverage, Medicare or Medicaid coverage, Diagnosis Related Group (DRG) case mix group, and whether the patient arrived as a transfer. Both models also controlled for the following hospital-level variables: teaching status, urban location, bed size, and geographical region. The main outcome measure was total cost of hospital admission per patient-billed hospitalization. Outcomes such as length of stay and the effects of nurse staffing variables on outcomes were explored using similar modeling approaches.

EHR use is measured using stages based on individual applications reported in the hospitals. These include stage 0 (no automation), stage 1 (automation of ancillary services including a clinical data repository, and pharmacy, laboratory, and radiology information systems), stage 2 (stage 1 + automation of nursing work flow with electronic nursing documentation, and medication administration records), and stage 3 (advanced EHR including: stages 1 and 2 + CPOE and clinical decision support). Since meaningful use criteria are consistent with stage 3 adoption of EHR, we chose to compare hospitals that have advanced EHRs with all others, and this staging system has been used in previous research.[17]

Generalized linear modeling techniques were used to test the hypothesis that the total costs per admission were different between hospitals with and without advanced EHRs. To correct for the non-normal distribution of costs, gamma-distributed generalized linear models using a logarithmic transformation[18] were analyzed using the PROC GENMOD module in the SAS statistical software (version 9.2; SAS Institute Inc, Cary, North Carolina). The use of a gamma-distributed generalized linear model with a log-transformed link function has been shown to be an accurate method to estimate healthcare cost distributions that are generally right-skewed, especially when the log-transformed dependent variables do not have heavy tails or excessive heteroscedasticity such as was found to be true in these data.[19]

We controlled for potential selection bias of advanced EHR use in hospitals and potential differences in patient demographics, severity, and hospital case mix through the use of a propensity score stratification. To calculate the propensity score, a logistic regression analysis was performed to estimate the propensity of each patient to be seen in a hospital with advanced EHRs. Use of a propensity score approach can remove upward of 95% of bias from estimates.[8] Generalized estimating equation (GEE) methods were used to confirm that results remained the same after accounting for correlated outcomes across patients treated within the same hospital. We examined the potential for selection bias due to case mix, patient characteristics, and hospital characteristics in a sensitivity analysis using a 5% random sample of the data. This sensitivity analysis using a portion of the data in a propensity score–matching methodology allowed us to estimate the potential selection bias of known confounders that might have remained after using propensity score stratification methods. The data were prohibitively large, thus limiting propensity score–matching sensitivity analyses to a 5% sample. An additional sensitivity analysis was performed to assess the potential hidden bias potentiated by unknown confounders.[20] This allowed us to examine how much the inferential findings of cost differences could be altered by hidden biases of various magnitudes and how large these differences would have to be to alter the qualitative conclusions of our study.

RESULTS

The analysis included 5,047,089 individual patient cases. Of these, 1,509,610 (29.9%) patients were cared for in hospitals that use advanced EHRs. There were 550 hospitals included in the analysis, and of these, 104 (18.9%) use advanced EHRs. The mean overall total cost per admission was $10,790, with the mean cost for patient admissions at hospitals with advanced EHRs being $10,203 and the mean cost for patient admissions at hospitals without advanced EHRs being $11,010. Other descriptive information about the patients and hospitals are provided in **Table 1**.

When controlling for patient and hospital characteristics in the multivariable model, the mean cost per patient admission for hospitals without advanced EHRs was $7938. The mean cost per patient admission for hospitals with advanced EHRs was $7207. Based on the generalized linear regression model, presence of an advanced EHR was significantly associated with cost of admission, and the beta of –0.0966 indicates that patients treated in hospitals with advanced EHRs have costs that are on average 0.0966%, or $731, lower than those for patients treated in hospitals without an advanced EHR. Other significant predictors of cost include, as expected, patient age, race, gender, severity of illness, risk of death, transfer status, case mix, and insurance type, as well as hospital size, type of hospital, teaching status, rural or urban location, and region of the country. The estimates of the multivariable model are presented in **Table 2**. When the propensity score adjustment was included, the association between advanced EHR use and cost remained statistically significant, with cost estimates remaining the same, indicating

Table 1. Descriptive Data

	Total (N = 5,163,794) Mean (SD)	Advanced EHRs (N = 1,509,610) Mean (SD)	No Advanced EHRs (N = 3,654,184) Mean (SD)
Age, in years	48.3 (27.9)	45.9 (28.0)	49.3 (27.7)
Risk mortality	1.6 (0.9)	1.6 (0.9)	1.6 (0.9)
Risk severity	2.0 (0.9)	2.0 (0.9)	2.0 (0.9)
Cost per admission	$10,790 (17,857)	$10,203 (17,572)	$11,010 (17,993)
	N (%)	**N (%)**	**N (%)**
Medicaid	1,078,607 (20.9)	332,439 (22.0)	746,168 (20.4)
Medicare	1,899,951 (36.8)	4,979,650 (33.0)	1402301 (38.4)
Private insurance	1,717,720 (33.3)	529,941 (35.1)	1,187,779 (32.5)
Neonatal/maternal admit	1,177,819 (22.8)	364,631 (24.2)	813,188 (22.3)
Transfer into hospital	284,239 (5.5)	106,651 (7.1)	177,588 (4.9)
White	2,952,903 (57.2)	787,539 (52.2)	2,165,364 (59.3)
Black	587,325 (11.4)	206,575 (13.7)	380,750 (10.4)
Hispanic	623,272 (12.1)	171,195 (11.3)	452,077 (12.4)
Teaching hospital	2,525,001 (48.9)	970,582 (64.3)	1,554,419 (42.5)
Urban hospital	4,652,205 (90.1)	1,457,757 (96.6)	3,194,448 (87.4)
Small hospital	585,247 (11.3)	114,943 (7.6)	470,304 (12.9)
Medium hospital	1,239,321 (24.0)	386,845 (25.6)	852,476 (23.3)
Large hospital	3,339,226 (64.7)	1,007,822 (66.8)	2,331,404 (63.8)
Northeastern United States	1,405,749 (27.2)	573,844 (38.0)	831,905 (22.8)
Midwestern United States	668,842 (13.0)	303,385 (20.1)	365,457 (10.0)
Western United States	1,477,224 (28.6)	331,228 (21.9)	1,145,996 (31.4)
Southern United States	1,611,979 (31.2)	301,153 (20.0)	1,310,826 (35.8)

EHR indicates electronic health record.

that selection bias was likely minimal. The GEE model controlling for potential correlation between patients seen at the same hospital remained significant (*P* of advanced EHR =.04) and garnered the same results as seen in the generalized linear model.

Sensitivity Analyses

We developed a 5% sample of the data using propensity score matching based on the nearest neighbor-matching greedy algorithm approach. We limited the sample to 72,002 randomly selected observations from each group to keep computational time below 8 hours. Propensity scores in the original sample ranged from 0.012 to 0.921. The heterogeneity between the EHR and non-EHR admissions was well controlled by the matching, as illustrated by the decrease in the absolute standardized difference in the means for all the propensity score model variables before and after the match (**Figure**). The cost differences between the EHR and non-EHR admissions in the matched groups were slightly larger than the cost difference observed for the total data set (**Table 3**). The use of the GEE approach on the main data analysis did not make a significant difference in the results. We explored whether the observed relationship between advanced EHR and cost of care was also present for other measures of hospital resource use, and found $3305 lower total charges per admission when mean charges were modeled. When we explored length of stay (LOS), adjusting for covariates similar to the cost model, we found a mean LOS of 4.1 days for both groups (*P* =.84). The resource input data available in the data set were limited. However, hospitals with advanced EHRs appear to have had a slightly higher rate of nursing full-time–equivalent personnel per 1000 adjusted admissions (RNFTEs). The mean number of RNFTEs was 4.27 for the advanced EHR admissions and 4.15 for the comparison group in the propensity score–matched sample, for a difference of 0.09 (*P* <.0001) RNFTEs after controlling for covariates in the model.

When assessing hidden bias due to unmeasured variables, we used methods described by Rosenbaum to esti-

Table 2. Regression Parameters on Cost of Admission

	Parameter Estimate (β)	95% CI	*P*[a]
Advanced EHRs	–0.0966	(–0.0951 to –0.0981)	<.0001
Age	0.0023	(0.0022-0.0023)	<.0001
Female	0.0675	(0.0662-0.0688)	<.0001
Race			
Other	Ref		
White	–0.0445	(–0.0465 to –0.0426)	<.0001
Black	–0.0064	(–0.0089 to –0.0040)	<.0001
Hispanic	0.0053	(0.0028-0.0079)	<.0001
Risk mortality	0.0332	(0.0320-0.0343)	<.0001
Risk severity	0.2616	(0.2605-0.2627)	<.0001
Neonatal or maternal admit	–0.4830	(–0.4844 to –0.4815)	<.0001
Transfer into hospital	0.0466	(0.0445-0.0487)	<.0001
Case mix	0.4371	(0.4364-0.4378)	<.0001
Propensity strata	0.0155	(0.0139-0.0170)	<.0001
Hospital type			
Public	Ref		
Private NFP	0.0540	(0.0521-0.0559)	<.0001
Private FP	–0.0781	(–0.0807 to –0.0755)	<.0001
Teaching hospital	0.1175	(0.1156-0.1195)	<.0001
Urban hospital	–0.0444	(–0.0468 to –0.0420)	<.0001
Hospital size			
Large hospital	Ref		
Small hospital	0.0130	(0.0108-0.0152)	<.0001
Medium hospital	–0.1340	(–0.1355 to –0.1325)	<.0001
Insurance Type			
Other	Ref		
Medicare	–0.0354	(–0.0380 to –0.0327)	<.0001
Medicaid	0.0534	(0.0509-0.0560)	<.0001
Private	0.1013	(0.0990-0.1037)	<.0001
Hospital Location			
Southern United States	Ref		
Northeastern United States	0.1366	(0.1336-0.1397)	<.0001
Midwestern United States	0.1764	(0.1727-0.1801)	<.0001
Western United States	0.4333	(0.4316-0.4350)	<.0001

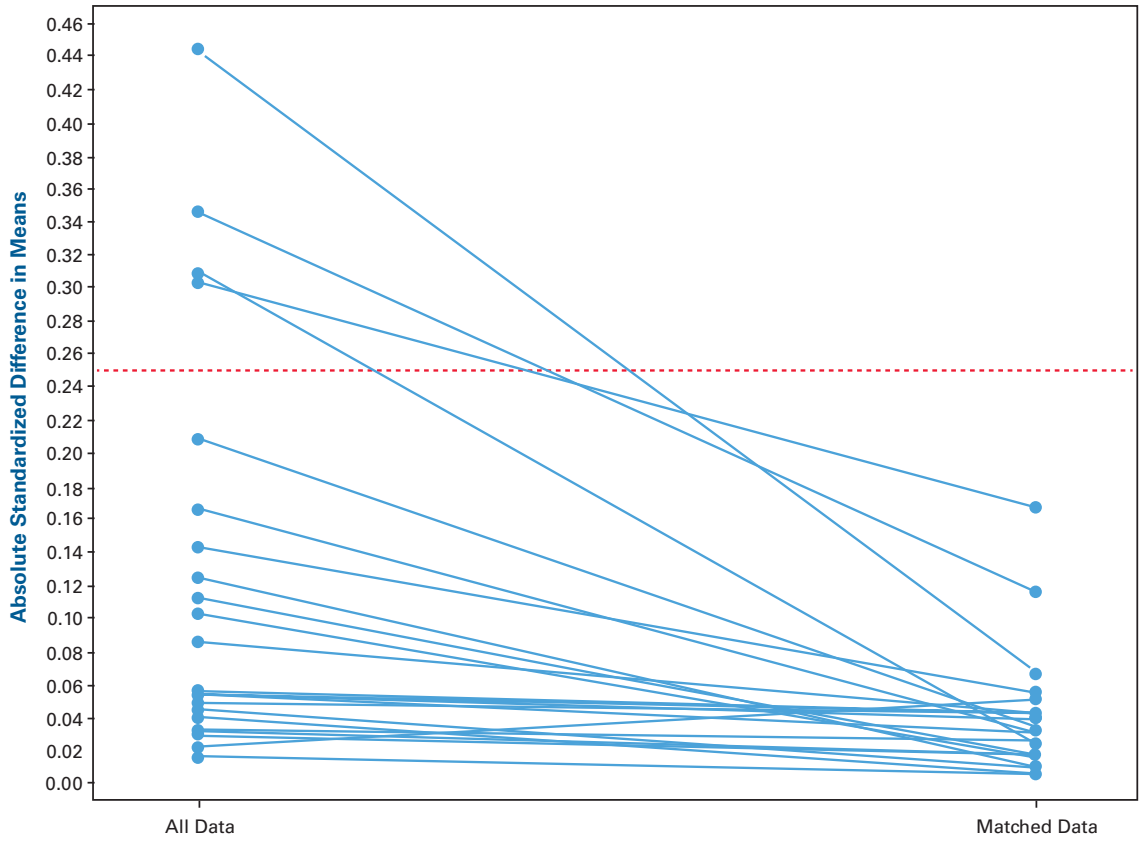
[a] *P* values were calculated using multivariable Log-linked Gamma Distributed Generalized Linear Model.
EHR indicates electronic health record; FP, for profit; NFP, not for profit.

mate the sensitivity parameter, Γ, the degree of departure from a study that is free of hidden bias.[20] In order to attribute the lower hospital cost in patients in an advanced EHR hospital to an unmeasured factor, a hidden bias or unobserved covariate would need to increase the odds of being in an advanced EHR hospital by more than a factor of gamma >100. The inferential finding of lower admission cost in patients seen in advanced EHR hospitals was, therefore, very insensitive to hidden bias.

DISCUSSION

Hospitals have struggled to adopt and use EHRs because they are costly to purchase, implement, and

Figure. Standardized Mean Differences Plot



maintain, especially in the current environment of cost containment and increased efforts to be "lean."[21] Thus, the HITECH incentives were created to help offset the costs by offering hospitals hundreds of thousands of dollars in payments for purchase and "meaningful use" of EHRs. This analysis provides evidence that advanced EHR use may result in cost savings for hospitals in addition to meaningful use incentives, and supports the business case for the costly implementation and maintenance of an EHR system. Such implementation should include plans for advanced EHR use.[22]

During the period of study, only a minority of hospitals were using advanced EHR systems.[23] The additional value of this study compared specific EHR components that are associated with stage 3, or meaningful use, and can be related to cost savings, including CPOE, clinical decision support systems, automation of ancillary services including a clinical data repository, pharmacy, laboratory, and radiology information, and automation of nursing work flow with electronic nursing documentation and medication administration records. The staging model that was used demonstrates that cost savings may not be realized until multiple features are included and implemented. Since EHR systems are complex and costly to implement, it is often a multistage process to adopt and use EHRs.[24] Thus, hospitals must anticipate that the financial savings may not exist until advanced, "meaningful" use is attained. The majority of hospitals have yet to reach the stage of implementation where cost savings are possible, since they are not using advanced EHRs.

The cost differences observed in this study were measured based on costs estimated from charges using the hospital's reported mean cost-to-charge ratio for the year of the data, and it is possible that this estimate of cost could bias cost estimates for an individual hospital. However, it is unlikely that systematic bias from this approach would have skewed our results. Given the findings of this study, patients and payer groups may consider selecting hospitals for care based on advanced EHR use, especially if they are paying for care based on a formula related to charges. This may be especially true if the efforts to promote consumer-driven healthcare are successful and if these hospitals demonstrate high levels of quality. However, given the current arrangement where hospital prices are not related to what patients have to pay, the cost savings of advanced EHR use may be most valuable to third-

Table 3. Cost Estimate Sensitivity Analysis

	Base Estimate Propensity Strata N = 5,163,794	Base Estimate Propensity Matched Sample N = 152,008
EHR cost/administration	$7207	$7103
Non-EHR cost/administration	$7938	$8005
Cost difference	$731[a]	$902[a]

P values were calculated using multivariable Log-linked Gamma Distributed Generalized Linear Model.
[a]*P* <.0001. *P* values were calculated using multivariable Log-linked Gamma Distributed Generalized Linear Model.
EHR indicates electronic health record.
Covariates include: patient age, gender, race, All Patient Refined Diagnosis Related Groups (APDRG) mortality and severity, neonatal or maternal status, private insurance coverage, Medicare or Medicaid coverage, Diagnosis Related Group (DRG) case mix group, and whether the patient arrived as a transfer, hospital teaching status, hospital urban location, hospital bed size, and hospital geographical region.

party payers. Our business case also does not include the costs of implementation or maintenance of an EHR system, which can be significant: they range from hundreds of thousands to millions of dollars.

This study had several limitations. First, EHR use is not randomly assigned, and thus there is the potential for selection bias. To overcome this, we included a propensity score adjustment. Second, the NIS data did not include a fully representative sample, and some of the states included in the sample did not provide hospital identifiers for patient-level data. Those cases were excluded from the study, as they could not be linked to EHR use data. Also, because the data are from 2009, we could not be certain that the systems classified as "advanced" in the adoption model absolutely meet the requirements for meaningful use according to the HITECH Act. However, given the definitions and components included in our definition, they are most consistent with meaningful use. There is a possibility that hospitals with EHRs are better able to capture charges. Better charge capture will result in higher estimated cost per admission in our data. Thus, if EHR use improves charge capture, costs (estimated as charges adjusted by the cost-to-charge ratio) will appear higher, resulting in a higher cost per admission in the advanced EHR group in the current study. Finally, some individual cases were excluded because the NIS data did not provide a hospital identifier to allow EHR use to be determined. While we did not find evidence that the excluded cases were systematically different than the included case, this does present a potential weakness.

CONCLUSIONS

Hospitals that use advanced EHRs report lower costs per patient admission than hospitals that do not use advanced EHRs. These cost savings will benefit many third-party payers, hospitals, and patients, and incentives such as those provided through the HITECH Act to promote EHR adoption and use will benefit hospitals. Since many previous studies have shown that EHRs can improve the safety and quality of care in hospitals, the projected cost savings in this study provides additional motivation and builds the business case for hospitals to make the large investment in adopting and maintaining an EHR system. This study is a very large multistate study that is likely representative of national trends and builds upon previous work of cost savings associated with EHR use. The results provide support for the continued adoption and use of EHRs to improve healthcare through cost savings and quality improvements.

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