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The Effect of Electronic Health Record Implementation on Emergency Department Operational Measures of Performance

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Abstract

Objective—To study the effect of electronic health record (EHR) implementation on the operational metrics of a diverse group of community emergency departments (ED).

Methods—We performed a retrospective before/after analysis of 23 EDs from a single management group that experienced EHR implementation, defined as the date of implementation of electronic clinical documentation in the ED. We obtained electronic data for 4 length-of-stay (LOS) measures (arrival-to-provider, admitted, discharged and overall LOS) and 4 measures of operational characteristics (left-prior-to-treatment-complete, significant returns, overall patient satisfaction and provider efficiency). We compared the 6-month “baseline” period immediately prior to implementation with a “steady-state” period commencing 6 months after implementation for all 8 metrics.

Results—For the LOS measures, there were no differences in the *arrival-to-provider* interval (difference of −0.02 hours, 95% CI of difference −0.12, 0.08), admitted *LOS* (difference of 0.10 hours, 95% CI of difference −0.17, 0.37), *discharged LOS* (difference of 0.07 hours, 95% CI of

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Conflicts of Interest: None

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difference $-0.07, 0.22$) and *overall LOS* (difference of 0.11 hours, $-0.04, 0.27$). For operational characteristics, there were no differences in the percentage who left-prior-to-treatment-complete (difference of 0.24%, 95% CI of difference $-0.47\%, 0.95\%$), significant returns (difference of -0.04% , 95% CI of difference $-0.48\%, 0.39\%$), overall percentile patient satisfaction (difference of -0.02% , 95% CI of difference $-2.35\%, 2.30\%$) and provider efficiency (difference of -0.05 patients/hour, 95% CI of difference $-0.11, 0.02$).

Conclusions—There is no meaningful difference in 8 measures of operational performance for community EDs experience EHR implementation between a baseline and steady state period.

Keywords

electronic health records; performance measures; implementation

Introduction

Background

Electronic health records (EHR) have the potential to improve the quality, safety, and efficiency of health care delivery.^{1–12} To accelerate the adoption and use of EHRs, the federal government is providing \$17 billion to incentivize the adoption and meaningful use of health care information technology (HIT) with penalties for hospitals and providers that do not comply by 2015.^{13,14} Although emergency physicians and management groups are not eligible to receive incentive payments, emergency department (ED) EHR use can support the fulfillment of hospital-specific meaningful use criteria, so there is a shared motivation to adopt ED HIT.¹⁵

Importance

Hospitals are increasingly adopting and using EHRs in response to these national policies;¹⁶ however, less attention has been paid to the impact on workflow, efficiency and accuracy of documentation.^{17,18} Recently, the economic and operational benefits and projected cost savings of HIT have been called into question.¹⁷ Emergency clinicians often complain that EHRs slow them down, are difficult to use and are limited by repetition of canned phrases.¹⁷ These operational challenges are particularly important in the ED, which plays a critical role in the healthcare system as the primary source of admission to hospitals, supporting primary care practices and serving as a vital safety net for society's most vulnerable patients.¹⁹ Additionally, the ED is one of the largest contributors to overall hospital operational efficiency.²⁰ As a result, streamlined patient flow and provider efficiency in the ED are fundamental to delivering high quality care not only to the ED, but throughout the hospital and health system. Several groups have found that length of stay increased during ED EHR implementation with a return to baseline in the post-implementation ramp-up period.^{21–23} Other studies have found conflicting results with reduced length of stay and improved efficiency.¹ However, these are single site studies at academic facilities limiting the generalizability of their findings. As hospitals and EDs continue to adopt EHRs, continued investigation is needed to better understand and find ways to mitigate disruptions associated with EHR implementation and to maximize operational efficiencies.

Goals of Investigation

We sought to study the effect of ED EHR implementation on operational metrics before and after steady state of implementation across a broad range of EDs. Our goal was to describe how an aggregate group of EDs responded to EHR implementation, not the factors associated with returning to baseline. We hypothesized that ED performance measurements will return to baseline after implementation.

Methods

Study Design, Setting and Selection of Participants

In January 2013, we collected data from an enterprise data warehouse created by Schumacher Group, a multi-state, diverse management group, herein referred to as “the management group”, that provides physician and midlevel provider services for EDs and other clinical settings. The management group provides emergency care in 27 states, including approximately 160 hospital-based ED sites. Each individual facility transmits electronic and scanned paper charts daily to a centralized location to be stored in an internal storage management system. The management group uses trained personnel to extract uniform data fields from scanned copies of heterogeneous documentation systems. A group of 30–40 rotating data abstractors were trained with the management group's data extraction processes. Initially a supervisor oversaw all data extraction. As accuracy and reliability improved, direct supervision gradually decreased, transitioning to sample audits for ongoing monitoring of data quality. Data extractors use standardized processes and standard fields, and data was subsequently stored in an enterprise data warehouse. The data extraction process occurs routinely, whether an EHR was being implemented or not, as a part of the management group's quality and informatics processes. All data extractors were blind to the presence of a study, its purposes, the facilities under review, and the duration of review. Time stamped data were preferentially used. However, if time stamps were unavailable, time entered by nurses or physicians in the EHR was used. Our inclusion criteria were facilities within the management group's purview that implemented an EHR in the ED in the previous 36 months. Specifically, in order to be included, sites had to have electronic operational data available for one year immediately prior to EHR implementation and one year after implementation.

To operationalize the definition of “EHR implementation” we first had to define this event. An ED EHR is specifically designed to manage data and workflow in support of ED patient care and operations, including patient registration and tracking, clinical documentation, computerized provider order entry, results reporting, and discharge management.²⁴ ED EHR components can be implemented all together or in phases. ED charting consumes a significant portion of ED physician time²⁵ and concerns for increased time for electronic documentation are a common barrier to EHR implementation.²⁶ Some evidence suggests ED electronic documentation is more time consuming than paper documentation.^{27,28} Given that only 60% of US EDs have implemented electronic charting²⁹ and the potentially significant impact of electronic clinical documentation on ED efficiency, we defined ED EHR implementation as the time when a new electronic clinical documentation system was implemented.

Methods and Measurement

Availability of data depended upon the variable, whether the individual institution collected the data and the frequency with which it was collected. When provided to the study investigators, individual facility data were de-identified to both institution and patient. A sample data file was sent to investigators to ensure data appropriateness; the remaining data files were sent for each facility. To ensure the quality of data received and entered, the management group undertook multiple processes in an iterative fashion to achieve high quality data as part of its regular data warehousing effort. All data cleaning was performed by the management group. On a monthly basis, individual provider results were evaluated and compared within each facility setting. Multiple individual provider metrics were reviewed using outlier analysis for the top and bottom performing 20% and then discussed with respective medical directors to ensure fidelity. Next, facilities with EHR implementations in the past 90 days were scrutinized with daily evaluations of data field completeness, accuracy and performance measures to identify system or individual provider problems and to immediately address any identified issues. Third, the management group's aggregated measures are compared with hospital measures of the ED and providers to identify any potential gaps or inaccuracies.

Data Management

Data management policies were determined *a priori* to receipt of electronic data files. All data was received as aggregated monthly means by facility. Visit-level data were not provided for analysis. Individual facility data for each operational metric were evaluated using the same 3-step approach. First, we evaluated each operational metric on the monthly level for missingness, then for negative values and lastly for implausible values. All negative values were removed from the data since negative values cannot occur for the measures of performance used in this study. Missing data were not replaced with imputed values. However, if more than 2 of data points in either the pre- or post-implementation phases (on the monthly level) were missing for a specific metric, the facility was not included for that operational measure. Individual facility values were also evaluated for implausible aberrancies which could skew our results. Since we were using means, aggregated monthly means greater than 2 times the mean for that metric's respective pre- or post-implementation period, were not included as they were likely errors.

We obtained demographic measures of each facility from the management group's data set, including annual volume, location, for-profit status of the facility, characteristics of the hospital, contract start date, census division, EHR implementation date, current and prior documentation system type (i.e. paper or electronic charting system). We asked the management group to use the zip code of the facility to identify a Rural-Urban Commuting Area (RUCA) code v2.0 to classify location. RUCA codes were developed to classify census tracts as either rural or urban.³⁰ We used the four category classification scheme where 33 different RUCA codes are aggregated into four types: urban, large rural, small rural and isolated to categorize facilities.

Outcomes

When possible, we used standard and accepted operational metrics and definitions^{31,32} for emergency care to assess ED performance during EHR implementation. Using this list of operational metrics, we evaluated metrics that would be readily available and consistent across multiple facilities including length of stay and measures of quality (e.g. return visits) as well as patient-centered metrics (e.g. patient satisfaction). We assembled a list of ideal performance metrics and submitted them to the management group. We selected length of stay measures as our primary outcome because we knew that these would be readily available at facilities. Secondary outcomes were operational characteristics including left prior to treatment complete, patient satisfaction, provider efficiency and significant returns. Specific operational metrics not available included race, acuity of patients, use of scribes and midlevel providers, medication dosages and features of each EHR implementation. We defined left-prior-to-treatment-complete as those patients that left against medical advice plus those that left without being seen. Significant returns were defined by each individual facility but could include such measures as 48 or 72 hour return to the ED, return visit to the ED and subsequent admission, death or transfer. Overall percent patient satisfaction was the value obtained from patient satisfaction survey data and was defined by each of the survey instruments used to collect these data. This measure was used to assess patients' satisfaction with the care received during their ED experience. Lastly, provider efficiency was defined as the number of patients with a disposition made by the provider per-hour.

Analysis

Data were analyzed retrospectively using SPSS v21 (IBM Corporation, Armonk NY). Monthly data were evaluated relative to the month of EHR implementation to allow for a standardized comparison of months relative to when EHR implementation occurred. Since these data were already aggregated as a mean on the monthly level, we calculated a mean of the monthly means for each operational metric. Despite the use of time data, we used a mean because we assumed a normal distribution since these were aggregated data and histogram plots demonstrated a normal distribution appearance. While operational data is typically non-parametric, we had no measures of uncertainty to be able to assess the nature of these data. For each metric, we compared the 6-month periods immediately prior to EHR implementation and defined this as the 'baseline' period. We used the same 6-month period 1 year later which we defined as the 'steady state' period, or beginning 6 months following EHR implementation. Previous research from our group has found that EHR implementation can result in a temporary period of disruption up to 4 months.²³ Therefore, we reasoned that 6 months would provide an adequate buffer for facilities to return to their baseline and to achieve a steady state of normal ED operations. We computed the mean of a mean and calculated the standard deviation for the difference between steady state and baseline. Since we did not have monthly census numbers, we calculated an aggregate mean by variable not weighted for patient volume. Next we calculated the 95% confidence interval of the difference before and after.

Results

Characteristics of study subjects

We identified 23 EDs that met our study inclusion criteria. Table 1 provides a summary of the characteristics for the 23 EDs included in the study. All facilities were community, non-academic EDs in the Southern Census Region. Five of the 23 facilities were not-for-profit facilities. The annual census for each ED ranged from 8,000 to approximately 60,000 patients seen annually. The self-pay populations at these facilities ranged from 8–31%, emergency medical service (EMS) arrivals between 4–21% and between 4–24% of patients were admitted. Based on the four category classification scheme of RUCA codes, we included 10 urban facilities, 8 large rural, and 5 small rural locations. No isolated locations were included. Of the 23 EHR implementations, 21 represented transitions from paper to electronic documentation and occurred between March, 2008 and November, 2011. Eight distinct clinical documentation systems were implemented across the 23 facilities.

Main Results

The number of facilities with data, by operational metric, are available in Table 2. Of the operational metrics, the *arrival-to-provider* interval, *admitted LOS*, *discharge LOS* and *overall LOS* were consistently available across facilities and used in our analysis. When evaluated using 95% CI of the mean difference, there was no statistical difference in the baseline and steady state periods for the *arrival-to-provider* interval, *admitted LOS*, *discharged LOS* and *overall LOS* (Table 2). When evaluating operational characteristics, there was again no statistical difference between the baseline period and steady state for left-prior-to-treatment-complete, significant returns, overall percent patient satisfaction and provider efficiency (Table 2). Each of the performance measures can be seen with respect to time before and after EHR implementation in Figures 1 and 2. Results by individual facility for 4 operational metrics are available in Figure 3.

Limitations

While we found that EHR implementation does not affect 8 operational measures of ED performance, our results must be considered in light of several limitations. First, our study evaluates the average effect across 23 facilities. Some facilities performed much better than the mean and some much worse. However, the focus of our study was of the average effect of EHR implementation on ED performance. Individual facility results vary and can be seen in Figure 3. Our study also does not focus on the ramp-up period of EHR implementation as several studies have already well highlighted the disruption caused by the ramp-up period immediately following EHR adoption.^{21,22} Our results have face validity, showing a disruption in operational measures immediately after introduction of EHR technology (Figures 1 and 2); however, our study focuses on the long-term performance across a series of operational measures of performance. Second, not all operational measures were available and this study is not a comprehensive assessment of the effect of EHRs on clinical care and delivery. For example, acuity, laboratory, diagnostic testing and medication administration data were not reviewed to assess test ordering which has been found to be affected by EHR implementation.^{21,22,33,34} This limits our understanding of the measures we do have, but

also are possibilities for further research, especially at the individual facility level. Acuity, for example, limits our understanding of the severity of illness and its effects on operational metrics. Additionally, we do not know about additional patient safety, quality measurements and usability of the EHR implemented. While there may have been no change in the performance measurements assessed, there could have been a substantial change in patient safety or other dimensions of care that would critically affect the way any results are viewed.

In our study, we also standardized our analysis by months relative to EHR implementation. As a result, we did not account for time of the year, only time relative to EHR implementation. For example, one facility may have been in the steady state during a busier period than another facility. However, one facility's peak volume period may not be another facility's peak time. Additionally, we used a convenience sample of sites with sufficient data available to analyze before and after EHR implementation. Considering this was a convenience sample, we did not do a formal power analysis. Our study also does not include qualitative elements of each implementation since this was a retrospective study and most of the facilities transitioned from paper to electronic records. Additionally, we did not control for the number of EHR modules available in each implementation. For example, if one facility only implemented physician documentation, but another implemented physician documentation and results viewing, we did not control for this. In addition, we did not have data on any temporary or long-term steps facilities may have taken to mitigate the impact of EHRs on ED performance metrics, such as adding additional providers or scribes and using speech recognition. Such information would provide valuable insight into the processes undertaken to implement health information technology in the ED.

Additionally, some operational metrics may be defined or collected differently at each facility. For example, different patient satisfaction survey instruments may be collected or a facility may define "significant returns" differently than another facility. However, the management group uses these measurements equally in practice and in the data set; therefore, we did as well.

While our study includes a broad range of facilities, it is not completely representative of all types of facilities. Our study only includes facilities in the Southern census region, however, the census areas and location categories represented in this study are broad. Lastly, this study only considers a single management group. Organizational policies and additional operational support may have influenced the progression from baseline through initial implementation to steady state and affected the rate at which these facilities achieved a new steady state following EHR implementation. Studying alternative management practices may reveal differences in culture, preparation, implementation processes, operational response, operational support, and ultimate results of the EHR implementation.

Discussion

To our knowledge, this is the largest study of EHR implementation and its effect on ED performance measures and the only one to evaluate community EDs. In this study, we found no statistical nor operationally meaningful differences in 8 measures of operational

performance in 23 community EDs between the baseline period and the steady state period one year later. While we were limited in the number of performance measures that we could evaluate, the operational metrics included reflect time-based measures, measures of efficiency, quality and a patient-centered perspective. On average, all 8 of these measures showed no statistical difference after a steady state was achieved.

Our study included a broad array of locations (i.e. urban versus rural) and facility types (i.e. patient volume, EMS populations and admission proportion). While previous studies on ED EHR implementation have occurred in academic facilities, this study provides evidence of the effect of EHR implementation in non-teaching hospitals which represent nearly 80% of US hospitals.^{1,21,22,34,35} The number of performance measures used along with the array and number of facilities evaluated adds to the robustness of our findings that there was no meaningful difference in ED performance metrics between the baseline period and a steady state period following EHR implementation. Given the reported number of benefits to be found from EHR implementation, enhanced operational performance, when viewed through the lens of the performance metrics used in this study, do not appear to be one of them. However, the lack of a positive finding does not eliminate the possibility of benefits from EHRs for clinical and patient care. There are additional dimensions by which to assess the incorporation of EHRs that were not evaluated in this study. They include financial performance, order entry/decision support and clinical documentation which can improve providers' ability to share information with other clinical providers which affect patient safety and the quality of care delivered.¹ In fact, the lack of a negative finding may further support the call for clinical entities, particularly EDs, to move to electronic systems since operational performance may not be diminished once a steady state is achieved. Moreover, emergency care is one component of the entire health care system and does not represent the other clinical arenas which may or may not experience operational gains or losses associated with EHR implementation. If the operational effects of EHR implementation in one clinical setting are offset by effects in another, with a net positive, then perhaps the overall benefit of the EHR implementation could be worth the investment.

The knowledge gained from this study is an important contribution to the debate about EHRs and their effect on health care, particularly emergency care. While we used aggregated measures of performance in our study, in analyzing individual facilities, some facilities performed significantly above and below the mean and were substantially altered after EHR implementation. This facility-to-facility variation is a tremendous opportunity for future research to identify the underlying factors leading to these performance variations. Future directions could include understanding the factors associated with the reasons why some facilities are operationally enhanced by EHRs or degraded by EHR implementation. Doing so could go a long way to better understanding how to take advantage of the financial investment in healthcare information technology. This could be the result of better preparation through the use of clinical champions, better organizational buy-in, effective leadership and change management and ultimate commitment to information technology that contribute to an ED's response to EHR implementation.³⁶⁻³⁸ Qualitative methods may be well suited to better understanding why facilities respond the way they do and how they can affect workflow delivered in a healthcare setting.^{27,39} By mitigating inefficiencies

gained by implementing EHRs, we may enhance the overall benefit of an electronic record and the subsequent value delivered to the patient and the healthcare system.

In summary, on average, EHR implementation at 23 diverse community ED facilities did not change 8 common performance measures of ED operations when comparing a prior baseline with a post-implementation steady state period. Further research is needed to elucidate how facilities respond to EHR implementation and to better understand the operational costs and benefits of such technology implementation.

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Figure 1.

Length of stay for door-to-provider, admitted, discharged and overall by month for one year before and one year after EHR implementation. The numbers along the x-axis represent the midpoint of each month's performance before (negative) and after (positive) implementation. The dashed line indicates the month of EHR implementation.

Note: EHR, electronic health record.

Figure 2.

Operational metrics relative to time (in months) from EHR implementation. The numbers along the x-axis represent the midpoint of each month's performance before (negative) and after (positive) implementation. The dashed line indicates the month of EHR implementation.

Figure 3.

Standardized performance by facility before and after EHR implementation for 4 operational metrics. A positive value represents superior performance relative to the other facilities whereas a negative value represents inferior performance. For example, superior performance for length of stay would be a reduction in time, but for patient satisfaction would represent an increase in percent satisfied.

Note: EHR, electronic health record.

Table 1

Two year operating environment characteristics of EDs that implemented an electronic health record system.

Facility	ED Census (Patients)	Hospital Beds	Hospital Profit Status	Location Classification	Self- Pay	EMS Arrivals	Hospital Admits	Date of EHR Implementation	Original Documentation System	New Documentation System
1	36,629	181	For Profit	Urban	30%	16%	14%	Jul-2010	T-System	ProMed
2	47,140	91	For Profit	Urban	22%	15%	14%	Mar-2008	T-System	ProMed
3	60,840	222	For Profit	Urban	28%	11%	15%	Mar-2008	T-System	ProMed
4	44,118	170	For Profit	Large Rural	24%	15%	13%	Jul-2010	T-System	ProMed
5	60,552	170	Not For Profit	Urban	26%	10%	11%	Feb-2010	T-System	Allscripts
6	33,075	70	For Profit	Urban	12%	4%	4%	Jun-2008	T-System	ProMed
7	24,559	52	For Profit	Large Rural	19%	12%	8%	Jun-2011	T-System	Medhost
8	21,600	95	For Profit	Small Rural	16%	15%	12%	Jun-2011	T-System	Medhost
9	41,570	161	For Profit	Large Rural	20%	13%	11%	May-2011	T-System	Medhost
10	61,577	180	Not For Profit	Large Rural	19%	20%	15%	Apr-2010	T-System	McKesson
11	39,143	281	For Profit	Urban	20%	20%	24%	Nov-2011	ProMed	Medhost
12	31,037	106	For Profit	Urban	21%	15%	9%	Jul-2011	T-System	Medhost
13	52,316	149	For Profit	Large Rural	24%	12%	8%	Jul-2011	T-System	Medhost
14	50,940	28	Not For Profit	Urban	31%	7%	5%	Sep-2009	T-System	T-System EV
15	63,197	56	For Profit	Large Rural	16%	9%	13%	Oct-2011	ProMed	Medhost
16	56,886	110	For Profit	Urban	18%	13%	15%	Jun-2010	T-System	ProMed
17	25,126	111	Not For Profit	Small Rural	19%	14%	7%	Nov-2008	T-System	Epic
18	56,063	166	Not For Profit	Small Rural	24%	12%	11%	Apr-2010	T-System	Meditech
19	27,261	80	For Profit	Small Rural	20%	21%	16%	May-2011	T-System	ProMed
20	38,207	187	For Profit	Urban	8%	10%	10%	May-2008	T-System	ProMed
21	8,621	40	For Profit	Small Rural	22%	19%	8%	Mar-2009	T-System	ProMed
22	37,739	196	For Profit	Large Rural	23%	19%	14%	Jul-2008	T-System	ProMed
23	30,443	45	For Profit	Large Rural	28%	12%	10%	Aug-2011	T-System	Medhost

ED, emergency department; EMS, emergency medical services.

Table 2

Operational characteristics of emergency departments for months 7 to 12 after electronic health record implementation compared with a baseline period one year earlier.

<i>Length of Stay (hours)</i>	<i>N</i>	<i>Baseline</i>		<i>Steady State</i>		<i>95% Confidence Interval of Difference</i>	
		<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Lower</i>	<i>Upper</i>
Arrival-to-Provider	17	0.65	0.29	0.63	0.26	-0.12	0.08
Admitted	23	4.60	0.78	4.70	0.82	-0.17	0.37
Discharged	23	2.40	0.45	2.47	0.47	-0.07	0.22
For All Patients	23	2.73	0.49	2.85	0.53	-0.04	0.27
<i>Operational Characteristics</i>							
Left Prior to Treatment Complete	23	3.18	2.05	3.42	1.84	-0.47	0.95
Significant Returns*	17	1.00	0.97	0.96	1.34	-0.48	0.39
Overall Percent Patient Satisfaction	16	82.69	3.16	82.67	5.62	-2.35	2.30
Provider Efficiency (Patients/hour)	23	1.69	0.38	1.65	0.34	-0.11	0.02

* Patients that return after care is initially provided in the emergency department and are determined by each facility