The impact of electronic health records on care of heart failure patients in the emergency room

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ABSTRACT

Objective To evaluate if electronic health records (EHR) have observable effects on care outcomes, we examined quality and efficiency measures for patients presenting to emergency departments (ED).

Materials and methods We conducted a retrospective study of 5166 adults with heart failure in three metropolitan EDs. Patients were termed internal if prior information was in the EHR upon ED presentation, otherwise external. Associations of internality with hospitalization, mortality, length of stay (LOS), and numbers of tests, procedures, and medications ordered in the ED were examined after adjusting for age, gender, race, marital status, comorbidities and hospitalization as a proxy for acuity level where appropriate.

Results At two EDs internals had lower odds of mortality if hospitalized (OR 0.55; 95% CI 0.38 to 0.81 and 0.45; 0.21 to 0.96), fewer laboratory tests during the ED visit (−4.6%; −8.9% to −0.1% and −14.0%; −19.5% to −8.1%) as well as fewer medications (−33.6%; −38.4% to −28.4% and −21.3%; −33.2% to −7.3%). At one of these two EDs, internals had lower odds of hospitalization (0.37; 0.22 to 0.60). At the third ED, internal patients only experienced a prolonged ED LOS (32.3%; 6.3% to 64.8%) but no other differences. There was no association with hospital LOS or number of procedures ordered.

Discussion EHR availability was associated with salutary outcomes in two of three ED settings and prolongation of ED LOS at a third, but evidence was mixed and causality remains to be determined.

Conclusions An EHR may have the potential to be a valuable adjunct in the care of heart failure patients.

BACKGROUND AND SIGNIFICANCE

Changes in health status drive care transitions between home, community, and healthcare settings.[1] Care transitions are associated with information gaps, communication breakdowns, and lack of coordination, which can lead to inefficiency, errors, safety risks, redundant work, and patient dissatisfaction. Transitions to the hospital emergency department (ED) are especially problematic. If driven by a sudden and unexpected event at home, the workplace, or elsewhere in the community, the patient is likely to arrive with no readily accessible, prior clinical information. In one metropolitan setting, information gaps occurred in a third of patients presenting to the ED, with clinicians rating the importance of the missing information as very important or essential in 48% of cases.[2] Gaps were associated with prolonged stay and increased costs of redundant testing and other assessments. But addressing these information gaps is not easy. In a survey of ED physicians, 86% of respondents rated it difficult or extremely difficult to obtain additional clinical information from outside providers and reported that their attempts to obtain such information failed more than half of the time.[3] Perhaps not surprisingly, the majority indicated that they would request such information for less than 10% of their cases.

The electronic health record (EHR) holds promise to close such gaps and thereby lead to improved care quality and efficiency.[4 5] In recent years enthusiasm has grown for the broad deployment of EHR systems that make clinical information more accessible, are interoperable (ie, they can share information between systems and process that information), and are interconnected to facilitate health information exchange (HIE) at a community, regional, or national level. Indeed, the USA is in the midst of a national quest to achieve this objective.[6] Conceptually, an EHR augmented with HIE can provide a timely and succinct summary of prior clinical information requiring little provider effort to obtain and use. But prior research on the value of EHRs in resolving information gaps, with or without HIE, has been limited in scope and sample size and has produced mixed results.[7–9]

OBJECTIVE

In 2003 three large health systems in the Twin Cities that had or were about to install an EHR system from the same vendor to support all or part of their clinical operations foresaw the potential to exchange clinical information. They joined in an effort to determine if sharing clinical information would have an impact on clinical care and outcomes. An initial study was formulated to examine the incremental value for patients of having prior clinical information in a health system's EHR compared to patients without such records. We hypothesized that patients presenting to the ED who had an existing electronic record would be less likely to experience information gaps and consequently receive better quality and more efficient care than similar patients who had no accessible prior clinical information. We assumed that use of available EHR information might lead to improved decision-making because the clinical team would be better informed and be aided by decision support features.

MATERIALS AND METHODS

Study design

We conducted a retrospective, cross-sectional, observational study and employed secondary data analysis to compare measures of utilization and outcomes for two patient groups: those with prior clinical information in the health system's EHR at the time of ED presentation and those without. The study focused on patients with congestive heart failure (CHF), a common chronic illness with exacerbations which frequently result in ED visits and rehospitalizations.[10] Prior clinical information is likely to exist for CHF patients and be relevant to clinical decision-making during subsequent visits.[11 12] The study sample was drawn from patients visiting any of the selected EDs over a 19-month period from June 1, 2006 to December 31, 2007. Two of the EDs agreed to participate in an additional 15 months of data collection that ended on March 31, 2009. At each site the sample included all patients 18 years or older who presented within the timeframe and had an International Classification of Diseases, Ninth Revision - Clinical Modification (ICD-9-CM) code representative of CHF associated with their ED visit. To avoid multi-visit contamination, only the first appearance of a patient in each ED during an observation period was used and designated as an index visit. Only the data associated with that encounter and any immediate subsequent hospitalization in that healthcare system were included in the analysis. Patients were classified as internal if they had had a substantive clinical encounter documented in the associated health system's EHR prior to the index visit. Otherwise patients were classified as external. Substantive clinical encounters were comprised of hospital, ED, or ambulatory/office clinical encounters but were not limited to those involving CHF. We excluded other administrative contacts (eg, making appointments, social work, registration, correspondence) and certain simple clinical contacts (eg, prescription renewal, immunizations) that generated no physician content. Our study protocol was reviewed and approved by the institutional review board of each of the participating health systems as well as that of the University of Minnesota.

Setting

One ED from each health system was selected for observation based on its patient volume, perceived high prevalence of out-of-system patients, metropolitan location, and broad geographic coverage. Because some of the research data and subsequent conclusions could be deemed sensitive in the local competitive healthcare market, it was agreed that the participating ED sites would not be further identified. ED providers working in any one of the health systems were able to access electronic records only for patients who had previously received care within that health system. Additional information could be sought in the usual way via interview and requests to outside providers. Paper records with past clinical information were not readily accessible to clinicians at any site. Two of the health systems used the same commercial EHR system to document information about a patient's ambulatory, ED, and hospital visits, while the other used that vendor's system for documenting ambulatory care but a different commercial EHR to document inpatient and emergency care. Each health system had deployed its EHR independently, resulting in EHRs with differing implementation times and, consequently, differing amounts of prior clinical information. The mean duration in years between each index visit and the earliest substantive visit preceding it ranged from 2.08 (SD 1.29) to 9.36 (SD 4.07) years. Clinicians within a health system had the ability to access that system's inpatient and ambulatory records, but evidence of their access to such records was not available to us.

Data collection and preparation

Each health system used a clinician-reviewed ICD-9-CM code set to identify CHF patients who had been seen during the observation period in its ED billing data and then extracted data from its clinical data warehouse for these patients. These data included age at the index visit, gender, race, marital status, and information about previous visits. For the index visit, encounter-level data included ED arrival and departure times, ED disposition status, laboratory tests (at the orderable level), diagnostic procedures (primarily imaging studies and ECGs), medications ordered, diagnosis codes associated with the index visit, and, if hospitalized, hospital admission time, discharge time, and discharge status. Date/time data were based on system timestamps and those with unreliable or outlier timestamps were excluded. At one site we observed and excluded one patient whose ED length of stay (LOS) was zero hours and 28 cases for which the ED LOS exceeded 24 h, since the latter were deemed to be most likely due to administrative rather than clinical issues. All data provided to the research team had anonymous unique identifiers substituted for patient identifiers and were covered by formal data use agreements.

Outcome measures

We hypothesized that the availability of prior clinical information would diminish information gaps and be associated with better quality and more efficient care. As surrogates for quality of care, we used the hospitalization rate, inpatient LOS, and inpatient mortality rate. We excluded ED mortality from analysis after finding only a single death reported in the EDs during the observation periods. Knowledge of recent laboratory tests and diagnostic procedures could reduce ordering and medication lists could limit additional prescriptions. The numbers of laboratory orders, diagnostic procedures, and medications ordered during the index ED visit were used as surrogates for efficiency of care. We also examined ED LOS as there is concern that the time to a disposition decision may be prolonged if there is additional clinical information to review.[3]

Covariates

In order to account for some likely alternative explanations of any observed differences in the outcomes, we included age, gender, race, and marital status in the analyses. Recognizing that the burden of illness is strongly associated with patient outcomes, we included a Charlson comorbidity index (CCI) based on diagnoses that the patient had at the time of the index ED visit[13 14] using existing algorithms with minor modifications.[15 16] We recognized that the CCI, while predictive of certain patient outcomes, did not adequately represent the severity of the patient's condition (ie, acuity level) at the time of the index visit. Under the assumption that the higher the acuity, the more likely a patient was to be hospitalized, we used whether or not the patient was admitted to the hospital directly from the ED as a gross proxy measure of acuity where appropriate. While it would have been desirable to have a more precise measure of acuity, such information was not available for the EHR records provided to us and since they were anonymized we had no means of collecting additional data on these patients.

Statistical analysis

The initial descriptive analysis as reported in table 1 revealed that there were differences in population characteristics among

Table 1 Descriptive statistics of study patients

ED site	Patient characteristics	All	Internal	External	p Value*
A	Observation period (months)	34			
	Number of patients (%)	2077	1327 (63.9)	750 (36.1)	
	Mean age (SD), years	75.7 (14.4)	75.3 (14.1)	76.3 (15.1)	0.01
	Female (%)	53.4	53.4	53.3	0.99
	Married (%)	39.8	42.7	34.6	<0.001
	Race, white (%)	87.6	89.9	83.4	<0.001
	Mean Charlson comorbidity index (SD)	3.3 (2.0)	3.4 (2.0)	3.2 (1.9)	0.13
	Hospitalization rate (%)	94.7	93.2	97.2	<0.001
B	Observation period (months)	19			
	Number of patients (%)	1686	1448 (85.9)	238 (14.1)	
	Mean age (SD), years	72.3 (15.6)	72.5 (15.4)	71.0 (16.5)	0.26
	Female (%)	50.7	51.7	44.1	0.03
	Married (%)	37.1	36.4	42.7	0.09
	Race, white (%)	79.3	79.8	65.9	0.03
	Mean Charlson comorbidity index (SD)	3.8 (2.3)	3.8 (2.3)	3.7 (2.4)	0.14
	Hospitalization rate (%)	96.7	96.5	97.8	0.33
C	Observation period (months)	34			
	Number of patients (%)	1403	1199 (85.5)	204 (14.5)	
	Mean age (SD), years	79.1 (12.0)	79.7 (11.6)	75.7 (13.7)	<0.001
	Female (%)	53.2	53.9	49.0	0.20
	Married (%)	45.2	46.6	37.1	0.01
	Race, white (%)	96.3	97.0	91.9	<0.001
	Mean Charlson comorbidity index (SD)	2.9 (1.9)	2.9 (2.0)	2.6 (1.5)	0.11
	Hospitalization rate (%)	61.4	61.6	59.8	0.62

*Wilcoxon's rank sum test or χ^2 test.
ED, emergency department.

the three sites. Therefore, we chose to treat this analysis as a replication over the three sites by conducting those analyses within each site and examining the patterns that resulted. The variable internality was used to represent the internal or external status of each patient. Descriptive statistics were calculated and simple comparisons were conducted using the χ^2 test of independence, Wilcoxon's rank sum test, and analysis of variance as appropriate. Logistic regression analysis was used to investigate the influence of internality on hospitalization and hospital mortality adjusting for effects of age, gender, race, marital status, and the CCI. A generalized linear model with appropriate variance structure[17] was used to investigate the impact of internality on hospital LOS adjusting for the same covariates and on ED LOS using the acuity proxy in addition to the other covariates. Because the counts of test orders, procedures, and medications are highly skewed with large number of patients with no such orders (ie, zero counts), we undertook an analysis using the family of count data models that allow more appropriate analyses of this type of data. For a more detailed explanation of analytic models the reader is referred to our recent publication on this topic.[18] Appropriate count data models were used to analyze the count of laboratory tests, diagnostic procedures, and medications ordered incorporating the same covariates including the acuity proxy. When using these analytic models we selected the one that best fit the data. Poisson or negative binomial regression models were used when there was an indication that a single predictive model was the best fit to the data as reflected in either a Poisson or negative binomial distribution. The hurdle model was selected if analysis indicated that there were likely two processes that were involved in predicting a count. The logit part of the hurdle model aims to predict if a subject will have a zero count or not and produces an odds ratio of being in the zero counts group for each of the independent variables. The Poisson part models the positive counts (excluding zeros). The SAS software package V.9.2 (SAS Institute) was used for all analyses.

RESULTS

There were 5166 patients 18 years or older who met the eligibility criteria, with 3974 (77%) determined to be internal patients. Table 1 presents basic demographic information on the study subjects at the three sites. When patients' demographic factors were compared by internality, the only statistically significant pattern was that at each site internal patients were more likely to be Caucasian than external patients. There were no significant differences in the degree of comorbidity between internal and external patients at any of the sites. We have reported the values of the covariates in table 1 for completeness. Some of them are significantly related to our outcome measures as expected. However, after table 1 we focus our discussion only on the effects of internality since these represent the potential impact of an EHR adjusted for the effects of these covariates.

The effects of internality on ED and hospital LOS, hospitalization rate, and in-hospital mortality are depicted in table 2. Hospitalization, hospital LOS, and hospital mortality have been adjusted for age, gender, race, marital status, and comorbidity. ED LOS has been adjusted for the same covariates and the acuity proxy. After adjustment, ED LOS was found to be longer for internals at site B (32.3%; 95% CI 6.3% to 64.8%; p=0.01) but similar at sites A and C. Internality had no effect on hospital LOS at any site. At site A, internal patients had lower odds of being hospitalized (0.37; 95% CI 0.22 to 0.60; p<0.0001) and, if hospitalized, lower odds of death in the hospital (0.55; 95% CI 0.38 to 0.81; p=0.003) than external patients. At site B, there were no differences in the odds of either hospitalization or mortality. At site C, as was the case at site A, the odds of death in the hospital were significantly lower (0.45; 95% CI 0.21 to 0.96; p=0.04) for internal patients than external patients.

Table 2 Impact of internality on length of stay, hospitalization rate, and hospital mortality

		Exp (β‡)		
Outcomes	**Independent variables†**	**Site A**	**Site B**	**Site C**
ED LOS	Internality (ref: external)	0.998	1.323*	0.991
	Age	1.002*	1.000	1.002
	Sex (ref: female)	0.975	1.001	0.960
	Race (ref: non-white)	0.948	0.978	1.022
	Marriage (ref: single)	1.000	0.953	0.985
	Charlson comorbidity index	1.006	0.993	1.008
	Hospitalized? (ref: no)	1.213**	0.820*	1.165**
Hospital LOS	Internality (ref: external)	0.948	0.757	0.886
	Age	0.994**	0.991*	0.998
	Sex (ref: female)	0.960	1.014	0.930
	Race (ref: non-white)	1.257**	1.191*	1.021
	Marriage (ref: single)	0.986	0.992	0.963
	Charlson comorbidity index	1.111**	1.062**	1.128**
		OR		
Outcomes	**Independent variables†**	**Site A**	**Site B**	**Site C**
Hospitalization rate	Internality (ref: external)	0.367**	0.667	0.982
	Age	1.013*	0.990	0.994
	Sex (ref: female)	0.923	1.145	1.020
	Race (ref: non-white)	1.609	1.006	1.599
	Marriage (ref: single)	1.019	0.465*	1.081
	Charlson comorbidity index	1.641**	2.139**	1.877**
Hospital mortality	Internality (ref: external)	0.552*	0.743	0.449*
	Age	1.013	1.027*	1.033*
	Sex (ref: female)	0.861	0.989	1.063
	Race (ref: non-white)	1.451	1.310	0.661
	Marriage (ref: single)	1.238	1.326	0.803
	Charlson comorbidity index	1.248**	1.107*	1.116

*p<0.05, **p<0.001.
†ref denotes the reference group to which another group is compared to determine changes in outcome.
‡β: regression coefficients of the generalized linear models for ED and hospital LOS; Exp is the exponential function.
ED, emergency department; LOS, length of stay.

Table 3 depicts the effects of internality adjusted for all covariates on the numbers of laboratory tests, procedures, and medications ordered in the ED using best-fit models identified in the table for the count of those resources ordered at each site. At site A, internal patients were estimated to have 4.6% fewer laboratory tests than external patients (95% CI −8.9% to −0.1%; p=0.04). At site B, there was no such difference. At site C, as portrayed in the column labeled 'n=0', the odds of an internal patient having zero laboratory test orders was no different from that of external patients. But among patients with at least one laboratory test order at site C, internal patients had 0.86 times the number of tests of external patients on average. In other words, internal patients had 14.0% fewer laboratory tests (95% CI −19.5% to −8.1%; p<0.0001) than external patients. Internal patients had 33.6% fewer medications (95% CI −38.4% to −28.4%; p<0.0001) at site A and 21.3% fewer (95% CI −33.2% to −7.3%; p=0.004) at site C.

DISCUSSION

Main discussion

Our analyses revealed various differences that may shed light on the influence of an EHR on care of CHF patients in the ED. At both sites A and C, internality was associated with differences involving hospital mortality and the number of laboratory tests and medications ordered in the ED. In other words, patients with CHF who had some clinical information available within a healthcare system's EHR when they presented to these two ED sites, had fewer laboratory tests ordered in the ED, fewer medications ordered, and greater odds of surviving if hospitalized. Internal patients were less likely to be hospitalized at site A but not at site C. Site B appeared to be different from the other two with only one significant finding—ED LOS was longer on average for internal patients. There was no difference at any site between internal and external patients in the number of procedures ordered in the ED or in hospital LOS.

The reduction in the number of laboratory tests ordered in the ED at sites A and C that we observed is consistent with the findings of Stair[19] and Overhage[7] and with our own earlier analysis of a smaller dataset which included patients with diabetes and asthma.[20] Recent broad, national studies of the impact of EHR systems on healthcare costs and quality which included heart failure patients, have shown little difference between hospitals that have adopted EHR systems and those that have not.[21 22] However, they did not examine patient outcomes with respect to the presence or absence of prior clinical information. In the present study, all of the participating health systems were early EHR adopters and the study was focused on performance differences within an institution related to the existence or lack of clinical information in an EHR at the time of presentation to the ED.

When considering the magnitude of the effects, it is interesting to note that the reduction in the number of laboratory tests, when statistically significant, was small (4.6% at site A and 14% for patients with at least one test at site C). In contrast, the reduction in medications was substantial (33.6% at site A and 21.3% at site C). Perhaps decisions to perform laboratory tests would not be affected much by prior information given the emergent CHF patient presentation in the ED that usually requires a comprehensive, current picture of the patient, but such information becomes more valuable when the decisions focus on the choices of medications prescribed. While this study was not aimed at identifying mechanisms for the observed findings, it suggests that a large part of cost-savings might be through reduction in unnecessary prescriptions rather than laboratory tests. More studies should explore this observation further.

Because the clinical impact of information technology is dependent on the services deployed and many other local contextual issues,[23 24] it is not surprising that results varied among the three EDs, each housed in a different health delivery system. That a reduction in mortality and numbers of laboratory tests and medications was found in at least two of the three EDs provides some but not conclusive evidence to support our hypothesis regarding the positive impact of an EHR.

Internal patients had a significantly longer ED LOS at one site. While we do not have definitive evidence that this difference is related to the presence of EHR technology, it does correspond to a concern expressed by a majority of surveyed emergency physicians that HIE would increase or greatly increase the time to a disposition decision.[3]

Because the odds for hospitalization and in-hospital mortality were reduced and some reductions in resource use for patients with CHF were seen, the potential economic impact may be substantial for a nation that expended nearly $40 billion on CHF healthcare in 2007.[25] In 2007 CHF was the third most common diagnosis in ED patients among those between 65 and 84 years of age and the most common diagnosis for those 85 and older.[26]

Limitations

While our investigation has revealed a number of positive associations between EHR availability and improved hospital-

Table 3 Adjusted comparisons between internal and external patients for the numbers of laboratory tests, procedures, and medications ordered during the index visit

Outcomes	Independent variables†	Site A	Site B	Site C	
				Hurdle model	
	Best-fit model	Negative binomial, Exp (β‡)	Negative binomial, Exp (β‡)	n=0§	n>0
Laboratory tests	Internality (ref: external)	0.954*	0.990	0.643	0.860**
	Sex (ref: female)	1.092**	1.021	0.779	0.983
	Age	0.999	0.997*	1.008	0.997*
	Marriage (ref: single)	0.992	1.003	1.189	0.944*
	Race (ref: non-white)	1.029	1.089	0.664	1.152*
	Charlson comorbidity index	1.020**	1.011	0.861*	1.014*
	Hospitalized? (ref: no)	1.912**	1.236*	0.053**	1.373**
	Best-fit model	**Negative binomial**	**Negative binomial**	**Negative binomial**	
Medications	Internality (ref: external)	0.664**	0.793	0.787*	
	Sex (ref: female)	0.943	0.839*	1.038	
	Age	0.998	0.987**	0.995*	
	Marriage (ref: single)	1.022	0.957	0.853*	
	Race (ref: non-white)	0.987	1.022	1.100	
	Charlson comorbidity index	1.038**	0.992	1.029	
	Hospitalized? (ref: no)	2.570**	2.155*	5.385**	
	Best-fit model	**Hurdle model**	**Hurdle model**	**Hurdle model**	
		n=0§ n>0	n=0§ n>0	n=0§ n>0	
Procedures	Internality (ref: external)	0.874 0.957	1.354 0.829	1.015 0.901	
	Sex (ref: female)	0.718 0.983	0.825 1.086	1.068 0.986	
	Age	0.996 1.003	0.988 1.008*	1.001 1.001	
	Marriage (ref: single)	1.057 0.999	1.301 1.010	1.218 0.958	
	Race (ref: non-white)	0.878 0.957	1.104 1.122	0.656 1.104	
	Charlson comorbidity index	1.025 1.008	0.988 0.977	0.990 0.995	
	Hospitalized? (ref: no)	0.162** 1.377*	0.583 2.085*	0.194** 1.391**	

*p<0.05, **p<0.001.
†ref denotes the reference group to which another group is compared to determine changes in outcome.
‡β: regression coefficients; Exp is the exponential function.
§The odds ratio of having a count of zero.

related outcomes and ED resource use, causality cannot be definitively established with the study design we used. The differences in care and outcome between the two patient groups could be a product of fundamental differences between the two patient groups not accounted for in this study rather than their experience in the ED and, for some, the hospital. By definition the patients with EHR information had a previous relationship with the health system that provided the ED service. If that relationship was prolonged and ongoing and if that health system provided better or more coordinated care than the norm for CHF patients, this could possibly result in internal patients being in a less precarious state of health. Or perhaps the absence of an EHR record was a marker of those with limited or no access to healthcare in recent years. Either of these states might explain the higher hospitalization and mortality rates of externals that we observed in some of the hospitals.

We did attempt to adjust for one of those potential alternative explanations with the data at hand by considering a gross (ie, bivariate rather than scaled) proxy for acuity. We made the not unreasonable assumption that patients who were hospitalized had a higher acuity level than those not hospitalized. Table 1 shows that internal patients were hospitalized significantly less often than external patients only at site A. There were no differences at the other two sites. Nevertheless, hospitalization was introduced as a covariate representing acuity level in the analysis of ED LOS and resource utilization measures including laboratory test orders, procedures, and medications. It is important to note that hospitalization was a significant predictor of ED LOS, laboratory test orders, procedures, and medication use across all three sites. Furthermore, with one exception (ED LOS at site B), these statistically significant findings consistently characterized hospitalized patients as using more resources that non-hospitalized patients during the ED visit. This finding argues that our analyses did separate out at least some of the effects of differential acuity represented by hospitalization from the effects of an EHR. Nevertheless, there may be remaining differences between internal and external patients due to more subtle levels of acuity for which we have not been able to adjust and thus we cannot completely rule out acuity as an explanation of some differences, particularly for hospitalization rates, hospital LOS, and in-hospital mortality for which we could make no acuity adjustment. Yet our findings for laboratory tests and medications did not disappear when adjusted for a gross measure of acuity represented by hospitalization, indicating some residual effect which may be due to the presence of an EHR for those variables and sites where they occurred.

Our study did not collect information on the clinician's access to information for an individual patient and so we are not able to relate a given diagnostic or treatment decision to observed use of existing clinical information in the EHR. The hypothesis that the availability of prior clinical information in an EHR can influence an outcome is predicated on the assumption that the information is consulted by a care provider. If the information is not consulted, a finding of no difference between internal and external patients would be more likely. Perhaps lack of use of available prior information in some settings partially explains

the non-significance of clinical effects we saw among the sites studied. The trend toward significant beneficial effects in most analyses indicates that this is a possibility. Therefore, results of this study are likely to be conservative estimates of the true effects of prior information in the EHRs. Nevertheless, they are estimates of effect that can be useful in other studies. On the other hand, the mechanisms by which prior information can have an effect are not necessarily limited to direct access by the treating clinician. The ED triage nurse may well access such information prior to the treating clinician seeing the patient and convey it verbally or through a written note. If this were the case, then there is a plausible mechanism for an EHR information effect on care even if the treating physician does not access it.

The study may also be limited by the lack of knowledge about how current or relevant to the index visit was the prior information that was in the EHR. Weight, blood pressure measures, and laboratory tests done years ago may poorly characterize the patient at the time of the ED visit and hold little value. If the ED visit was primarily for an unrelated condition such as acute lower back pain, the prior information about the incidental CHF may have little impact on the current care process. However, CHF is a chronic condition that influences care decisions in many contexts. Thus, over a number of encounters, information that a patient has CHF as supplied by the local EHR may make some contribution to the efficiency and quality of care. If it did not, we would expect to see no differences between the groups we studied.

The heterogeneity among the databases from which the research data were acquired could have led to systematic errors in data analysis. Although each health system had adopted the same vendor's EHR system, each had configured it independently and deployed it at various times over an almost 10-year span. They retained key data elements in different forms using different definitions and stored it using different data models. For example, numbers of laboratory tests, procedures, or medications may contain some artifacts of heterogeneity among the health systems (eg, different coding systems, different ways a particular order would be entered and represented in the system).

Future study considerations

The explanation for why EHR information might have the observed impact is not addressed in this study. For instance, in the sometimes hectic ED setting, we have not determined if clinicians usually access information in the EHR even if it is readily accessible. Nor have we looked at the specific effects of the EHR's order entry system which all of the organizations had in place. When an order is placed through computerized provider order entry (CPOE), prior clinical information may be accessed and used to influence decision-making, even without direct clinician viewing of the information itself. But CPOE also has a downside if it is not well-matched to ED workflow and task responsibility.[27] It is the province of future studies to confirm that an EHR-enabled environment gives rise to the observed benefits and to determine the mechanism by which they occur. If the salutary effects of an EHR we found are confirmed, other frequently occurring chronic diseases should be studied to better characterize parameters that may make prior information especially useful or not. Prior clinical information for some chronic diseases other than CHF may show a more compelling clinical impact.[28] Finally, the lengthening of ED LOS in patients with EHR information at one site needs confirmation and further investigation.

CONCLUSION

The existence of a prior electronic record for CHF patients in the ED was associated with a reduction in hospital mortality and the ordering of fewer laboratory tests and medications in some settings but not all. In one of our settings, ED visit LOS was somewhat prolonged in the presence of a prior electronic record. We do not have definitive evidence that these effects are due to the presence of the EHR. They may be attributable to some other systematic difference for which we have not accounted between patients with and without prior clinical information in an EHR. Nevertheless, the results we report point in the direction of some impact of an EHR on some measures of healthcare utilization and outcomes and lay the groundwork for further, more definitive studies in the area.

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