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ORIGINAL PAPER

The influence of EHR components on admission decisions

Ofir Ben-Assuli · Itamar Shabtai · Moshe Leshno

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Abstract Medical organizations adopt electronic health record (EHR) and health information exchange (HIE) interoperable technologies in order to provide vital medical information needed for medical decision-making. The use of such interoperable information may lead to increased quality of care and reduced unnecessary costs. The goal of this study was to characterize the specific data components that improve the process of medical decision-making in an emergency department (ED). The outcome measures were the decision to admit/discharge a patient and differences in single-day admission rates with/without using an interoperable EHR. A database containing 3.2 million ED referrals from seven main Israeli hospitals was subjected to log-file analysis. We found that viewing medical history via the interoperable EHR significantly affects admission decisions. The data show a reduction in the number of avoidable single-day admissions, but also an increase in the rate of prolonged admissions. Previous admissions, laboratory tests, imaging and previous surgeries were the most influential information components.

Keywords Admission decision · Electronic health record · Health information exchange · Information components

O. Ben-Assuli (✉)
Management Information Systems, Faculty of Management, Ono Academic College & Tel-Aviv University, Kiryat Ono, Israel
e-mail: ofir.benassuli@gmail.com

I. Shabtai
Computers and Information Systems program, School of Economics and Management, The College of Management Academic Studies, Rishon LeZion, Israel
e-mail: itamar@colman.ac.il

M. Leshno
Faculty of Management & Faculty of Medicine, Tel-Aviv University, Tel-Aviv, Israel
e-mail: leshnom@post.tau.ac.il

1 Introduction and background

The healthcare sector has adopted information technology in recent years to improve the medical decision-making process. These technologies, including the EHR and HIE systems, provide interoperability and enable the electronic movement of health related information among units and organizations in accordance to nationally recognized standards [15]. The ED is a major gateway for patient care, where physicians need information not only about immediate symptoms, but also past medical treatment, family history, and lifestyle. The availability of patient long term health conditions, including information about medications, diagnoses, recent procedures, and recent laboratory tests, is critical to forming an appropriate plan of care [2, 10]. When asked, most physicians stated that all types of clinical information are very important; however, most of them rated their use of clinical information as moderate or low, and only three types of information (diagnoses, previous medications and allergies) were rated high [9, 11].

In actual practice, physicians do not wait for the results of time-consuming diagnostic procedures [20], and even when such information is available, time constraints can restrict access [16]. One study showed that even though many ED physicians believe that the majority of their patients would benefit from longitudinal patient health information, they attempted to obtain such data less than 10 % of the time [10].

This article examines to what extent physicians utilize the various information components in diagnosing and admitting patients, especially in the highly-stressful ED context, with its complex conditions for providing medical care including time constraints and the enormous number of patients. The study focused on the main health maintenance organization (HMO) in Israel, which is also one of the world's largest non-governmental HMOs. The HMO owns seven general hospitals (all surveyed in this research). In 2004, the HMO deployed the EHR/HIE solution analyzed here. The EHR/HIE interoperable

solution securely shares medical information, creating a virtual patient record by logically connecting various healthcare information systems at the HMO's hospitals and clinics. The record contain historical data about the patient including chronic medications, adverse reactions, detailed lab and imaging results, past diagnoses, healthcare procedures, etc.

2 Objective and research hypotheses

2.1 Objective

The objective of this research is to assess the contribution of various information components (listed at Table 1) retrieved from an interoperable EHR (such as lab tests and previous admissions) to the physician's admission decisions in EDs.

2.2 Hypotheses

It was argued that there is a relationship between the viewing of medical history and an improved medical care including admission decisions [19]. To better understand this link, we examined the relationship between interoperable EHR usage and general admission decisions and formulated the following hypotheses:

H1 There is a relationship between using information components via the EHR and admission decision to a hospital. This was divided into two specific hypotheses:

- H1.1 There is a positive relationship between using information components via the EHR and the decision to admit a patient to a hospital.
- H1.2 There is a negative relationship between using information components via the EHR and the decision to admit a patient to a hospital, resulting in a single-day admission.

Table 1 Types of patient medical history data available to physicians via the EHR

Medical information components	Specifics
Hospitalizations	Previous visits and hospitalizations
Blood pressure	Patient's prior blood tests results
Community records	The patient's community visits
Laboratories	Previous lab tests
Pathology history	Patient's pathological history
Imaging	An online retrieval of patient's imaging
Demography details	Information regarding the demography of the patient
Surgical history	A list of previous surgeries

H2 The relationship between using **local** information components and admission decisions is stronger than the relationship between using **external** information components and admission decisions.

3 Methods

The research method selected for this study is track log-file analysis. This method typically employs statistical tools such as T-tests and logistic regressions [18]. The log-files were based on data from seven main hospitals owned by the main HMO in Israel from 2004 to 2007, which uses an EHR IS to share medical information from distributed health suppliers. The log-file consisted of about 3.2 million referrals i.e., the whole population in these hospitals.

3.1 The dependent variables

3.1.1 Admission decisions

One of the most important decisions in an ED is whether to admit or discharge a patient. We thus analyzed the impact of using various information components via the EHR on the proportion of admissions (out of the total number of referrals to the EDs). Admission decision was defined as a dichotomous variable to admit the patient to the ED (1 for admit decision and value=0 for discharge decision). This measurement scale has been used in previous research [12].

3.1.2 Single-day admission

Quantified whether a patient, as a result of the decision to admit, was admitted for a single day (coded 1) or for a longer period of time (coded 0). Existing scales have shown that such short-term admissions can be reduced using medical information [1, 7, 14]. We examined whether the proportion of single-day admissions fluctuates when patients' medical history is viewed via EHR. Similar to many EDs around the world, hospitals in Israel maintain observation wards in which patients are monitored for a period of 12–24 h. This period of observation was not included in the calculations of single-day admissions.

3.2 Main independent variables

3.2.1 Using the EHR

The patients in our study were divided into two groups: patients whose medical history was viewed via the EHR

and patients whose medical history was not viewed. Vest [17] found that system access was not random, and that specific patient factors increased the odds of information access. Shabtai et al. [14] showed that the use of medical records depends on the patients' specific problem, and Ben-Assuli et al. [1] showed that the use of medical IS depends also on the crowdedness level at the point of care. The term ' Using the EHR' refers to access to at least one of several medical information components in the EHR (see Table 1). This was measured as a dichotomous variable (1=the EHR was accessed; 0 if not).

We created a set of dichotomous variables to measure the impact of medical components on the dependent variables. These variables were measured as dichotomous variables (as used at Table 3):

1. Value=1: If a specific information component was viewed via the EHR during the period of evaluation in the ED.
2. Value=0: If a specific information component was not viewed via the EHR during the period of evaluation in the ED.

3.2.2 Type of insurance

The parameter of insurance is highly important for distinguishing between cases in which the medical history of patients is available and cases in which it is only partially available. A previous study [4] shows that EDs internals (patients with prior information in the EHR upon ED presentation) had lower odds of mortality if hospitalized, required fewer laboratory tests during the ED visit as well as fewer medications than the external population.

The EHR chosen for this study only provides full interoperable information on patients belonging to the main HMO, and only information regarding previous admissions to the same hospital are available for patients from other HMOs. To control for major discrepancies in the quality and the amount of medical information between the HMOs, a dichotomous variable was created (1—if the patient was a member of the main HMO or 0—if the patient was from other HMO).

4 Results

In order to test for differences in the continuous variables between the two groups, a *t*-test for independent samples was performed. To test for differences in continuous variables between more than two variables, a one-way analysis of variance (one-way ANOVA) was performed. Associations between dichotomous variables were tested by the Pearson Chi-Square test (the standard test to compare proportions) or Fisher's Exact Test.

4.1 Descriptive statistics

Table 2 below indicates that the majority of the ED patients in the seven hospitals belonged to the main HMO (2,358,896 out of a total of 3,219,910 referrals). It is important to note that the medical history of the patient was viewed in only 16.12 % of all the referrals to hospitals. Thus, 83.88 % of all referrals did not include any use of medical history. Moreover, in approximately a quarter of the admissions to an ED (23.73 %), medical history was viewed whereas in more than 76 % of all admissions medical history was not viewed at all. Thus consistent with previous studies, there was a relatively low level of use of medical history. Furthermore, there was greater use of medical history for patients who were members of the main HMO, for whom more extensive data were collected, compared to other

Table 2 The distribution of referrals by type of insurance and viewing medical history

Properties[a]		Number of referrals Total study sample: n=3,219,910 (100 %)	Number of admissions Total study sample: n=921,386 (100 %)
All insurances (%)***	EHR IS accessed	519,132 (16.12 %)	218,606 (23.73 %)
	EHR IS not accessed	2,700,778 (83.88 %)	702,780 (76.27 %)
The main HMO (%)***	EHR IS accessed	410,959 (17.42 %)	175,933 (25.20 %)
	EHR IS not accessed	1,947,937 (82.58 %)	522,265 (74.80 %)
Other HMO (%)***	EHR IS accessed	108,173 (12.56 %)	42,673 (19.12 %)
	EHR IS not accessed	752,841 (87.44 %)	180,515 (80.88 %)

[a] The total number of referrals and admissions is divided into patients whose historical data were viewed via the EHR and patients whose were not, and also between the main HMO population and other HMO populations. Each of these groups was similarly divided in terms of viewing or not viewing patients' historical data. For instance, if we add the number of main HMO admissions whose historical data were viewed (175,933) to the number of other HMOs admissions whose historical data were viewed (42,673), the result is the total number of patients whose historical data were viewed (218,606)

*** $p<0.001$, ** $p<0.01$, * $p<0.05$, + $p<0.1$; n/a not applicable (All tables below use same conventions)

HMOs (25.20 % in the main HMO compared to 19.12 % to the others). Still, even among members of the main HMO, the extent of use of medical history was low.

4.2 Results of regressions of information components

Multivariate logistic regressions were calculated on the independent variables: Admission Decisions and Single-Day admissions (yes/no). Three blocks of variables were run: 1) Block 1: Treatment variables (EHR component (see at Table 1) viewing, age, insurance provider and gender), 2) Block 2: Control variables for type of department (for example internal medicine and surgical), and 3) Block 3: Control variables for different hospitals (due to various differences such as policies). These regressions reflected the pure contribution of EHRs' information components to the rate of admissions and single-day admissions.

Table 3 presents the impact of medical components on admission decisions adjusted for age, type of insurance, gender, type of department and type of hospital. Past surgeries had the greatest impact on admission decision; when viewing this information component, the total number of admissions increased by 62.2 %. This component affected single-day admissions as well, leading to a 17.3 % reduction. Another reverse admission/single-day admission effect was found with regard to previous hospitalizations where viewing such protocols increased (52.3 %) the total number of admissions and decreased (12.4 %) the number of single-day admissions. A similar effect was found for the pathology component as well.

Generally, viewing information components led to a decrease in the number of single-day admissions and to an increase in the amount of the longer admissions (supporting our two hypotheses). However, viewing laboratory results from the system reduced both the number of admissions and the number of single-day admissions. Demography and community record results were not significant. Therefore, the use and consumption of medical services appears to depend on the patients' specific problem.

4.3 Results of regressions of information components – local vs. external

The examined interoperable EHR collects two types of historical medical information that contributes to admission decisions - local and external. Local refers to information created locally at the same hospital while external refers to information created at different hospitals and other points of care.

Table 4 shows the impact of viewing information components on admission decisions divided into viewing local vs. external data. Table 5 shows the impact of viewing information components on single-day admission decisions divided into viewing local vs. external data.

An interesting result was obtained regarding the impact of the local vs. external history on admission decisions. When admission decision was the dependent variable, the results show that when external information was viewed the number of admissions increases by 16.6 % ($p<0.001$) while

Table 3 Logistic regression on admission decision and on single-day admissions

Theory variables in the equation	Admission decision/single-day admission	B	S.E.	OR [95.0 % C.I.]
Hospitalizations	Admission decision	.421***	.013	1.523 [1.484–1.564]
	Single-day Admission	−.132***	.025	.876 [0.834–0.921]
Blood pressure	Admission decision	−.047n/a	.061	.954 [0.846–1.076]
	Single-day admission	.209+	.124	1.232 [0.967–1.570]
Community records	Admission decision	.027n/a	.029	1.028 [0.971–1.087]
	Single-day admission	.047n/a	.060	1.048 [0.931–1.180]
Laboratories	Admission decision	−.071***	.005	.932 [0.923–0.941]
	Single-day Admission	−.227***	.010	.797 [0.781–0.814]
Pathology	Admission decision	.125***	.024	1.134 [1.081–1.189]
	Single-day admission	−.080+	.050	.923 [0.836–1.018]
Imaging	Admission decision	.159***	.007	1.173 [1.157–1.188]
	Single-day admission	−.262***	.015	.770 [0.748–0.792]
Demography	Admission decision	−.041n/a	.032	.960 [0.902–1.022]
	Single-day admission	.016n/a	.064	1.016 [0.896–1.151]
Surgical	Admission decision	.484***	.024	1.622 [1.546–1.702]
	Single-day admission	−.190***	.049	.827 [0.752–0.911]

Block 2 (control for type of department), Block 3 (control for type of hospital) are not shown here, but were also included in the regression (All tables below use same blocks)

Table 4 Logistic regression on admission decision – local vs. external

Theory variables in the equation	Local/External	B	S.E.	OR [95.0 % C.I.]
Hospitalizations	Local information	.047^{+}	.034	1.048 [0.980–1.121]
	External information	.112***	.057	1.119 [1.000–1.252]
Blood pressure	Local information	.288***	.087	1.334 [1.124–1.583]
	External information	−.164***	.083	.849 [0.722–.998]
Community records	Local information	−.055^{+}	.030	.946 [0.892–1.003]
	External information	.200^{+}	.049	1.020 [0.926–1.123]
Laboratories	Local information	−.404***	.008	.668 [0.658–0.678]
	External information	−.182^{+}	.137	.834 [0.638–1.090]
Pathology	Local information	−.086***	.029	.918 [.867–.971]
	External information	.041^{+}	.041	1.042 [0.962–1.129]
Imaging	Local information	−.251***	.008	.778 [0.765–0.791]
	External information	.181***	.018	1.198 [1.156–1.241]
Demography	Local information	−.251***	.035	.778 [0.727–0.833]
	External information	.009^{+}	.067	1.009 [0.885–1.152]
Surgical	Local information	.124***	.027	1.132 [1.074–1.192]
	External information	.228***	.053	1.256 [1.131–1.394]

when local information was viewed the number of admissions increases by 42.9 % ($p<0.001$). Analyzing the contribution of the various components on admissions show that when local information was used blood pressure and past surgeries contributes to the increase in admissions while other components contributes to the decrease in admissions. When external information was used, imaging, past surgeries and hospitalization are the components that most contribute to increase in admissions.

When single-day admissions was the dependent variable, the results show that when external information was viewed the number of single-day admissions decreases by 12.7 % ($p<0.001$) while when local information was viewed the number of single-day admissions decreases by 14.7 % ($p<0.001$). Analyzing the contribution of the various components on single-day admissions show that when local information was used past surgeries, imaging, labs and hospitalization contributes to the decrease in single-day admissions. When external information was used, imaging contributed to the decrease in single-day admissions. The results show that, in most cases, information created locally has much stronger relationship

Table 5 Logistic regression on single-day admission decision – local vs. external

Theory variables in the equation	Local/External	B	S.E.	OR [95.0 % C.I.]
Hospitalizations	Local information	−.180***	.071	.836 [0.727–0.960]
	External information	.055^{+}	.119	1.057 [0.837–1.334]
Blood pressure	Local information	.161^{+}	.174	1.175 [0.836–1.651]
	External information	.136^{+}	.176	1.146 [0.811–1.618]
Community records	Local information	.131***	.063	1.140 [1.008–1.289]
	External information	−.051^{+}	.109	0.950 [0.767–1.177]
Laboratories	Local information	−.180***	.015	.835 [0.811–0.860]
	External information	−.189^{+}	.253	0.828 [0.504–1.360]
Pathology	Local information	−.067^{+}	.062	0.935 [.829–1.056]
	External information	−.018^{+}	.088	0.982 [0.827–1.166]
Imaging	Local information	−.203***	.018	0.816 [0.788–0.845]
	External information	−.261***	.040	0.771 [0.713–0.833]
Demography	Local information	.061^{+}	.071	1.063 [0.924–1.223]
	External information	.014^{+}	.144	1.014 [0.764–1.346]
Surgical	Local information	−.288***	.054	0.750 [0.674–0.834]
	External information	−.090^{+}	.113	0.914 [0.732–1.142]

with admission decisions than information that gathered from external sources.

5 Discussion

Using historical medical information provided by EHR/HIE interoperability technologies including various information components contributes to admission decisions and clearly reduces the number of single-day admissions for all patients, especially for main HMO patients. Additionally, there were higher accessing rates for patients insured by the main HMO, as compared to other HMOs, although both figures remained strikingly low.

A possible explanation for the differences between types of insurance is that the medical history of patients not insured by the main HMO is supplied by a system whose sole source of information is based on the same hospital as the current referral, rather than on interoperable medical information; therefore, this information may have been considered less comprehensive [3]. By contrast, for the main HMO patients, medical history is collected from previous hospitalizations in all hospitals as well as from many health suppliers such as laboratories; therefore, the information is regarded as exceptionally comprehensive and thus motivates physicians to use the system.

One possible explanation for the increase in ED admission decisions after accessing the interoperable EHR components could be related to the nature of medical problems that may tend to be more severe. Another explanation is that due to the decrease in single-day admissions the rate of long admissions increases. However, the findings suggest that short unnecessary admissions which are more related to lack of access to information can be prevented, in significant percentages, by using EHR components during the course of evaluation in the ED. The information components that contributed the most to reducing single-day admissions were previous hospitalizations, past laboratory results, imaging, and past surgeries. These components should thus be readily available for viewing to assist single-day admission decisions. In addition, when we analyzed the use of local vs. external information the results indicate that, in most cases, information created locally has much stronger relationship with admission decisions than information that gathered from external sources.

Thus, the decision not to view important information may actually reflect physicians' lack of time. This may encourage them to admit patients for a redundant single–day admission even if the information is readily available [10]. An example from this study results shows that viewing the information component of imaging, gathered from external sources can reduce the amount of single-day admissions in 22.9 % and thus help avoiding redundant short term admissions and saving costs.

5.1 Research contribution

The main goal in this study was to characterize the data components that improve the process of medical decision-making in EDs. Previous research has pinpointed differences in the use of information components across clinical specialties [14]. This characterization may help improve the appropriateness of test orders [11].

Second, we expanded research on admission decisions. We extended the results of a critical question in the ED: whether or not to admit the patient. We expanded our analysis to other outcomes (as compared to studies [5] and [14]). We used a unique comprehensive dataset since our population of patients consisted of the whole population. Consequently, our data included all the general hospitals that use the EHR IS.

Third, the findings may enable developers and designers of EHR/HIE technologies to better understand the specific components that affect IS meaningful use and the value of information. This, in turn, may help integrate the necessary information components into new and existing interoperable systems. The results suggest that, several changes may be worthwhile to implement in ISs. First, information components in the system screens could be changed to fit specific clinical case properties. It was already found that even when users were shown that previous data were available and the display was integrated into the user's normal workflow, they generally accessed the data less than half the time [10]. Therefore, it is crucial to supply and promote substantial data for each type of decision and diagnosis [10]. Information components should be designed to help physicians make meaningful use of information, to consider this information properly, and to arrive at good decisions [8]. Poorly organized information can cause as many errors in decisions as having too little information [16].

Primary care providers find it difficult to keep up with information generated across different episodes of care. This situation is exacerbated when it is not from the same provider [3, 11]. Understanding the most significant information components may provide some guidance in the allocation of resources in this difficult endeavor of keeping up with patients' medical information.

5.2 Avenues for future research

Adding the physician's attributes to the log-file such as personal identification might facilitate research on network externalities, diffusion theory and TAM [6]. Second, a more in-depth analysis of information components regarding several main differential diagnoses, may improve our understanding on the issue. Such specific results may even prove helpful in modifying long-held medical guidelines [13]. Third, the results from this research could be used to formulate

questionnaires to evaluate physicians' priorities regarding different information components and required medical tests.

Conflict of interest The authors declare that they have no conflict of interest.

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