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The Contribution of Information Technology to Emergency Medicine

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ABSTRACT

Information systems have been adopted in many fields including the healthcare industry. Indeed, keeping abreast of the advances of the technological age, many medical organizations have invested heavily in information technologies (IT), aiming at improving medical decision-making and increasing its efficiency. Despite their advantages, information systems do not always provide the vital medical information required for medical decision-making, and the decisions may result in a decreased level of quality of care and unnecessary costs.

The objective of this research is to evaluate the contribution of IT to decision-makers (physicians) at the point of care of emergency departments (EDs). We evaluate the contribution of the medical information to medical decisions by using two methods: the track log-file analysis and an experimental study. Our results lead to the major conclusion that using IT contributes to increasing the proportion of correct admission decisions.

Keywords

Medical Decision-Making, Medical Informatics, Electronic Medical Record.

INTRODUCTION

The healthcare sector has been investing heavily in IT in recent years (Goldschmidt, 2005), with the aim of improving medical decision-making and increasing its efficiency through improved medical processes, reduced costs and the integration of patients' data. Despite the advantages of such systems, the information that can be immediately accessed from the systems located in many of the hospitals' EDs is generally merely partial. The systems do not always immediately provide the vital medical information required for critical decision-making.

In the framework of this research, we examined the value of information which is derived based on the medical history of patients that is provided to a decision-maker in the high-stress environment of an ED, with its complex conditions for providing medical care, such as different levels of time pressure and huge numbers of patients. In addition, we tried to explore the circumstances under which this information makes a greater contribution to the quality of a decision.

RESEARCH BACKGROUND

The effects of medical information systems (IS) at the point of care have been studied in previous researches from different aspects. Yet, despite the increasing use of these systems by clinicians, there has been little research documenting the effectiveness of their use. Especially rare are studies dealing with the impact of online medical systems on the process of decision-making with the stressful ED environment.

Theoretical frameworks to assess the potential value of medical information have been established only in the recent years (Basu and Meltzer, 2007; Claxton, Sculpher and Drummond, 2002). Walker, Pan, Johnston, Adler-Milstein, Bates and Middleton (2005) showed that interoperability between healthcare providers would enable computer-assisted reduction of redundant tests and found positive financial returns. Shabtai, Leshno, Blondheim and Kornbluth (2007) evaluated the contribution of IT to improvement in the medical decision-making processes and concluded that the use of medical history of patients can improve decision-making in internal medicine departments. The expansion of our research includes analyses of decision-making such as: admission decisions and choosing the proper diagnosis. In addition, we innovatively included in the

research a unique DB of referrals of patients to the ED which consists of all relevant population for our study, rather than be satisfied with modest samples which only partially represent a valid population, as performed in the previous studies.

We show below some of the past studies:

- The introduction of additional information and care options increases decision complexity (Redelmeier and Shafir, 1995).
- Physicians retrieve only a limited amount of the relevant information without time constraints (Hersh and Hickam, 1998).
- Physicians use electronic medical records (EMR) systems for far fewer tasks than the systems supported (Laerum, Karlsen and Faxvaag, 2003)
- Determining diagnostic and therapeutic strategies using health information technology (HIT) (Shortliffe, 1987; Johnston, Langton, Haynes and Mathieu, 1994).
- A clinical support system effectively triages patients in an ED by using a limited amount of information (Michalowski, Kersten, Wilk and Slowinski, 2007).
- The increase in national health expenditures and the desire to improve the quality of healthcare are driving the widespread adoption of HIT (Goldschmidt, 2005).

A survey of the literature leads to various implicit and explicit recommendations for further research on the main issue that is the target of this research: the impact of medical information (obtained from medical information systems) on decision-makers (physicians). Specifically, we focus on the contribution of EMR systems as the source of the medical history in the EDs, rather than on other sources of medical information (such as: hard copy patient record, physical examinations or the patient complaint).

OBJECTIVES, RESEARCH QUESTIONS AND RESEARCH HYPOTHESES

Objective and Research Question

The main objective of this research is to assess the contribution of integrative medical IS to the physician's decision-making process in the high-stress environment of EDs. Hence, our major research questions are:

- What is the impact of medical information obtained by integrative medical IS in medical decision-making in an ED?
- How important is interoperability in the processes of medical decision-making in an ED?

Major Hypotheses

Admission decisions

We attempted to discover the relationship between the use of medical history and the general admission decision.

The use of medical history, a major variable in the research, is formulated on the basis of recorded data regarding the different types of viewed medical information regarding the patients. The use of medical history is a variable which measures the actual use decision-makers make of the medical history from a unique medical IS which operates as an EMR system.

Sox, Blatt and Higgins (2007) explained how, through the processes of decision analysis (such as admissions' decisions); a physician can reach valid, reasonable conclusions regarding medical treatment despite imperfect information about the patient. The authors emphasized the importance of medical history as a means to attain those conclusions. Walker et al. (2005) argued that there is a relationship between the reviewing of medical history and an improved medical care performance including admission decisions. Goldman, Crum, Bromberg, Rogovik, and Langer (2006) argued that children with abdominal pain receive a more effective medical care (including better admission decisions) when the physician reviewed the medical history.

The following hypothesis was tested:

H1: There is a relationship between viewing medical history (via the EMR system) and admission decision to a hospital. It was divided into two specific hypotheses:

H1.1: There is a positive relationship between viewing medical history (via the EMR system) and a decision to admit a patient to a hospital.

H1.2: There is a negative relationship between viewing medical history (via the EMR system) and a decision to admit a patient to a hospital, resulting in a single-day admission.

One of the most important decisions in an ED is whether to admit or discharge the patient. Furthermore, we observed how the proportion of single-day admissions fluctuates when a medical history of patients is inspected. We assumed that part of the single-day admissions are uncalled for, and could easily be prevented given a proper medical history. These scales have assisted researchers in previous studies in the field and there are researches which dealt with capabilities of reducing the short-term admissions (Shabtai et al., 2007; Denman-Johnson, Bingham and George, 1997).

Additionally, we differentiated between medical history which existed as local EMR in certain hospitals and medical history which was exclusively provided online by various interoperable services from several decentralized health suppliers. Thus, we tested the abovementioned hypotheses (H1) by checking the impact of the source of information (local or external) on the admission decisions (H1.a).

Differential diagnoses

Swap and Nagurney (2005) showed that certain elements of the chest pain history are associated with increased or decreased likelihoods of a correct diagnosis of acute myocardial infarction (AMI) and they identify those elements.

We checked the relationship between the viewing of medical history and performing a more accurate differential diagnosis (DD). Specifically, we checked whether an additional review of the medical history leads physicians to a more accurate DD. We formulated this statement into the following hypothesis:

H2: There is a positive relationship between viewing of medical history and choosing the correct DD.

METHODOLOGY

The research used two methods that were designed in order to complement and enrich one another:

- Track log-file analysis using statistical tools such as regression analysis provided us with a realistic view of the ED environment. (Main Method)
- Experimental study - Experiments that simulate the complicated reality of an ED environment, representing the decision process by means of decision trees. (Secondary Method)

The Track Log-File Analysis

The analyzed log-files were based on data from seven main hospitals owned by Clalit health maintenance organization (HMO) in Israel, which use an integrative IS to share medical information from distributed health suppliers. This system has the ability to share electronic medical information and integrative medical information between many distributed health suppliers (including external medical clinics, imaging institutions, labs and hospitals).

These following variables were derived from the log-file analysis:

- The independent variables: viewed medical history, type of medical insurance, ED unit, hospital and DD.
- The dependent variables: admission decisions and single-day admissions.

For research purposes, the patients were divided into two groups:

- Patients, for whom medical history was viewed via the IS, were defined as the research group.
- Patients, for whom medical history was not viewed via the IS, were defined as the control group.

The objective was to assess the actual effect of the use of information on the performance of physicians with regard to their admission decisions.

The Experimental Study

In the experimental study, we compared the performance of physicians who had access to complete clinical information on patients to that of physicians who lacked such access. The main stages of the experiment were:

- Selecting the medical scenarios – The cases have been chosen from the most common clinical scenarios in the national center for health statistics (NCHS¹). The selected scenarios also appeared on the books of the educational commission for foreign medical graduates² (ECFMG) in order to be recognized as having optimal credibility. According to the NCHS, the

¹ NCHS is the United States' principal health statistics agency. See at: <http://www.cdc.gov/nchs/>

² The ECFMG assesses the readiness of international medical graduates to enter residency or fellowship programs in the USA. See at: <http://www.ecfm.org/>

most common specific principal reason given by adult patients (aged 15 years and older) for visiting the ED was chest pain. We chose for our experiment this most common principal reason for visiting the ED, the chest pain, and within it the AMI diagnosis.

- Constructing the medical scenarios - The cases were developed by a panel of six senior physicians in cooperation with an international medical simulation center (MSR institution³) and were finalized with a pilot study. The technical data have been added to the ECFMG instructions from several previous relevant researches on chest pain and AMI diagnosis (Goldman and Kirtane, 2003; Lee and Goldman, 2000; Pope, Aufderheide, Ruthazer, Woolard, Feldman, Beshansky, Griffith, and Selker, 2000).
- The research took place in the form of a website-based application⁴ that served as an ED environment. In each experiment, the tested physician randomly received three scenarios with only one of the following access patterns: with a full mandatory access to the simulated IS or lack of any access to the simulated IS.
- In the course of the experiment, the tested physician decided on the medical strategy during all stages including:
 - Viewing medical history and the physical examination.
 - Designing the diagnostic workup plan.
 - Deciding on the DD and whether to admit/discharge the patient.

FINDINGS

The Track Log-File Analysis

Basic factual data

The analyzed log-files were retrieved from Clalit HMO integrative IS to receive integrative medical information from distributed health suppliers at the point of care. The objective was to assess the actual effect of the use of information provided by the system in EDs on the performance of physicians with regard to their various decisions. This objective was accomplished by analyzing the log-files of ED referrals during the years 2004 to 2007 (including admissions and discharges). The log-file consists of 3,219,910 samples of referrals (921,386 admissions and 2,298,524 discharges). We could not disclose the names of the hospitals that are involved for reasons of confidentiality and privacy.

Multivariate logistic regression findings

We perform logistic regressions for two independent variables: **Admitted** (dichotomous dependent variable: 1-admit or 0-discharge) and **Single-Day admissions** (dichotomous dependent variable: 1-if the patient has been admitted for a single day or 0-if the patient has been admitted for a longer period of time). The method for running the regressions consists of three blocks of variables:

- Treatment variables: **history viewed** (dichotomous: 1-if the medical history was viewed via the IS or 0-if the medical history was not viewed via the IS), **age** (continuous variable represents the age of the patient), **insurance** (dichotomous: 1-if the patient is a member of Clalit HMO, for whom full medical history is available via the IS or 0-if the patient is not a member of Clalit HMO) and **gender** (dichotomous: 1-male or 0-female).
- Control variables for type of department: (such as: internal medicine and surgical).
- Control variables for different hospitals (due to various differences such as policies).

The combination of those two regressions reflected the pure contribution of previous information to the actual current decision of admission and is especially important to the rate of short-term admissions. The objective of the multivariate logistic regression is to receive the statistical validity while the impact of the historical information is adjusted in relation to the remaining variables in accordance with the principles of regression as demonstrated in previous researches (Cabrera, 1994; Ford, 2002). The findings were valid and significant for almost each group that was examined: hospital, type of insurance, department type, various DDs and locality of information. Here are a few main research results:

³ MSR organization, an international center for medical simulation,. See at: <http://www.msr.org.il/>

⁴ The full experimental cases can be found at: <http://gsba-rs.tau.ac.il/MedicalED/> (The assigned number in each case is not necessary the same assigned number of each case in our analysis due to the random order of the cases).

Logistic regressions on admission decisions (H1):

Tables 1 and 2 present the outcomes of the logistic regression regarding the impact of the variable "history viewed" and other variables on the admission decision to a hospital and on the rate of single-day admissions.

Variable	B	S.E.	Sig.	Odds Ratio	95.0% C.I. for OR	
					Lower	Upper
HistoryViewed	.353	.004	<0.001	1.423	1.413	1.434
Age	.032	.000	<0.001	1.033	1.033	1.033
Insurance	-.097	.003	<0.001	.907	.902	.913
Gender	.150	.003	<0.001	1.162	1.155	1.169
Constant	-3.789	.007	<0.001	.023		

Table 1. Logistic regression on the decision to admit

Variable	B	S.E.	Sig.	Odds Ratio	95.0% C.I. for OR	
					Lower	Upper
HistoryViewed	-.174	.007	<0.001	.841	.829	.853
Age	-.021	.000	<0.001	.979	.979	.980
insurance	-.066	.006	<0.001	.936	.925	.948
Gender	.051	.006	<0.001	1.052	1.039	1.065
Constant	-.836	.022	<0.001	.433		

Table 2. Logistic regression on single-day admissions

Summary of results from tables 1 and 2:

- History viewing—when history is viewed the number of admissions increases by 42.3% ($p < 0.001$, adjusted odds ratio (OR) = 1.423) and the number of single-day admissions decreases by 15.9% ($p < 0.001$, adjusted OR = 0.841).
- Age—when the age of the patients increases in additional year, the number of admissions increases by 3.3% ($p < 0.001$, adjusted OR = 1.033) and the number of single-day admissions decreases by 2.1% ($p < 0.001$, adjusted OR = 0.979).
- Type of insurance—when the insured patients are members of the Clalit HMO, the number of admissions decreases by 9.93% ($p < 0.001$, adjusted OR = 0.907) and the number of single-day admissions decreases by 6.4% ($p < 0.001$, adjusted OR = 0.936).
- Gender—for male patients, the number of admissions increases by 16.2% in comparison to female patients ($p < 0.001$, adjusted OR = 1.162) and the number of single-day admissions increases by 5.2% ($p < 0.001$, adjusted OR = 1.052).

Findings of the contribution of the locality of information to admission decisions (H1.a):

Tables 3 and 4 below are edited with the regression results regarding the locality of information.

Variable	External History Viewed		Local History Viewed	
	B (S.E.)	OR (Sig.)	B (S.E.)	OR (Sig.)
HistoryViewed	.154 (.008)	1.166 (<0.001)	.357 (.004)	1.429 (<0.001)
Age	.033 (.000)	1.033 (<0.001)	.032 (.000)	1.033 (<0.001)
Insurance	-.096 (.003)	.909 (<0.001)	-.091 (.003)	.913 (<0.001)
Gender	.148 (.003)	1.16 (<0.001)	.150 (.003)	1.162 (<0.001)
Constant	-3.658 (.045)	.026 (<0.001)	-3.795 (.007)	.022 (<0.001)

Table 3. Logistic regression on the decision to admit for different locations of information

Variable	External History Viewed		Local History Viewed	
	B (S.E.)	OR (Sig.)	B (S.E.)	OR (Sig.)
HistoryViewed	-.136 (.016)	.873 (<0.001)	-.159 (.008)	.853 (<0.001)
Age	-.021 (.000)	.979 (<0.001)	-.021 (.000)	.979 (<0.001)
Insurance	-.065 (.006)	.937 (<0.001)	-.069 (.006)	.934 (<0.001)
Gender	.052 (.006)	1.053 (<0.001)	.051 (.006)	1.053 (<0.001)
Constant	-.859 (.026)	.424 (<0.001)	-.852 (.026)	.427 (<0.001)

Table 4. Logistic regression on single-day admissions for different locations of information

The results show that viewing two types of information contributes independently to admission decisions: local medical history from certain health institutes and information exchanged between several decentralized health institutes. Furthermore, local history contributes more than external history to the admit decisions, and the number of single-day admissions decreases slightly more when local history is viewed than when external history is viewed.

The Experimental Study

The sample was composed of 102 physicians (47 senior physicians and 55 non-senior physicians) who differed on a range of characteristics. In the sample, 53 physicians were provided with access to the simulated IS and 49 physicians were not. In general we had three designed simulated cases:

- In case 1, without any additional information from the simulated IS, the normative medical decision of the physician should be to discharge this patient and the main DD is not one of the diagnoses related to AMI. On the contrary, with additional information from the simulated IS, the normative medical decision of the physician should be to admit this patient and the main DD is one of the diagnoses related to AMI.
- In case 3, without any additional information from the simulated IS, the normative medical decision of a physician should be to admit this patient and the main DD is one of the diagnoses related to AMI. On the contrary, with the additional information provided by the simulated IS, the normative medical decision of the physician should be to discharge this patient and the main DD is not one of the diagnoses related to AMI.
- In case 2, which serves as a control case, in both cases (with or without additional information) the normative medical decision of the physician should be to admit this patient and the main DD is one of the diagnoses related to AMI.

We chose to show only the results of cases 1 and 3, since these are the two valid cases of the experiment (case 2, was verified to serve as a control case in our results, and is not shown here). Tables 5-8 present the regressions' outcomes regarding the impact of the **independent variables: history viewed** (dichotomous: 1-for physician who had access to the simulated IS or 0-for the physician who did not have such access), **seniority** (dichotomous: 1-for senior physician or 0-for intern physician), **specialty** (dichotomous: 1-for internal medicine or 0-for other specialties) and **Time** (continuous: measured in seconds) on the **dichotomous dependent variables: a decision to admit** to a hospital (1-admit or 0-discharge) and on the **main DD** (1-AMI DD or 0-not AMI DD).

Variable	B	S.E.	Sig.	Odds Ratio	95.0% C.I. for OR	
					Lower	Upper
HistoryViewed	2.576	.556	<0.001	13.147	4.421	39.103
Seniority	1.126	.512	0.044	2.91	1.003	7.412
Specialty	-1.363	.827	0.099	.885	0.679	0.997
Time	.225	.091	0.013	1.253	1.049	1.496
Constant	-2.972	1.006	0.030	.051		

Table 5. Case 1: Logistic regression on the decision to admit

Variable	B	S.E.	Sig.	Odds Ratio	95.0% C.I. for OR	
					Lower	Upper
HistoryViewed	2.539	.637	<0.001	12.663	3.637	44.090
Seniority	1.136	.534	0.033	3.113	1.094	8.860
Specialty	-0.599	.241	0.067	.0941	0.901	0.972
Time	.335	.112	0.007	1.312	1.151	1.457
Constant	-3.082	.668	<0.001	.046		

Table 6. Case 1: Logistic regression on the main DD (AMI DD)

Variable	B	S.E.	Sig.	Odds Ratio	95.0% C.I. for OR	
					Lower	Upper
HistoryViewed	-2.503	.675	<0.001	.082	.022	.307
Seniority	-1.061	.620	0.047	.346	.103	1.167
Specialty	-.112	.034	0.001	.894	.835	.956
Time	.541	.331	0.051	1.200	1.019	1.509
Constant	4.377	1.028	<0.001	79.621		

Table 7. Case 3: Logistic regression on the decision to admit

Variable	B	S.E.	Sig.	Odds Ratio	95.0% C.I. for OR	
					Lower	Upper
HistoryViewed	-1.327	.428	0.002	.265	.115	.613
Seniority	-.861	.411	0.027	.521	.305	.942
Specialty	-.091	.021	0.005	.954	.892	.994
Time	.669	.391	0.027	1.387	1.006	1.645
Constant	.857	.319	0.007	2.357		

Table 8. Case 3: Logistic regression on the main DD (AMI DD)

Summary of the results

- In general, the experiment results supported our results from the log-file analysis by supplementing statistical significance with clinical robustness.
- Viewing medical history contributes to improved admission decisions (adjusted to other independent variables). Not only does it clearly reduce the number of unnecessary admissions (case 3, $p < 0.001$), but it also clearly increases the necessary admissions for all physicians (case 1, $p < 0.001$).
- Viewing medical history assists in determining the correct main diagnosis (case 1 and case 3) and especially helps identify (case 1, $p < 0.001$) or refute (case 3, $p = 0.002$) an AMI diagnosis.

Table 9 presents all the hypotheses results:

Hypothesis	Method 1: Track log-file analysis Approved/ Rejected (Significant)	Method 2: Experimental study Approved/ Rejected Significant: (case 1,case3)
H1.1, H1.1.a: There is a positive relationship between viewing medical history and a decision to admit a patient to a hospital	$\sqrt{(<0.001)}$	$\sqrt{(<0.001, <0.001)}$
H1.2, H1.2.a: There is a negative relationship between viewing medical history and a decision to admit a patient to a hospital, resulting in a single-day admission	$\sqrt{(<0.001)}$	Not measured
H2: There is a positive relationship between viewing of medical history and choosing the correct DD	Not measured	$\sqrt{(<0.001,0.002)}$

Table 9. Summary of Hypotheses Results

CONCLUSIONS

In summary, our results lead to the major conclusion that viewing medical history using medical IS contributes to improved admission decisions. Additional specific conclusions:

- All sources of information contribute to improved admission decisions (local medical history slightly more than external medical history).
- Viewing medical history assists in determining the correct main diagnosis and especially helps identify or refute an AMI diagnosis.
- The contribution of medical information is affected by the experience of the decision makers, the type of task they are required to perform or decision they are required to make, and their specialty.

CONTRIBUTION

The main purpose of our research was to contribute to scientific knowledge by providing additional insight into various fields of medical informatics. We enumerate several contributions:

- Focusing on the stressful point of care of the ED, and using a unique database containing a sample population of patients from all the relevant population.
- Focusing on using integrative real-time medical information from decentralized medical suppliers.
- Shedding a light on the positive relationship between using medical history and performing a more accurate diagnosis.

The findings of this study may also contribute to medical technology designers (by promoting efficiency in the design of new medical IS and improving existing ones), to physicians (by enhancing the efficient use of information resources) and to patients (by improving healthcare services).

RESEARCH LIMITATIONS

We tried to recognize our limitations and took them into account. Here are a few examples:

- Different hospitals carry different policies regarding the use of the system. In the context of this research and in order to adjust our results to these differences, we controlled for these differences between the hospitals by using many methods such as: regressions, case study and experiments.
- The unknown medical state of the patient -In the log-file there is no direct explicit verbal information regarding the medical state of the patient (privacy clause). The significant results from our special experimental study were enlightening, diminishing this limitation.

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