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Ofir Ben-Assuli

Tel-Aviv University, Israel, ofir.benassuli@gmail.com

Moshe Leshno

Tel-Aviv University, Israel, leshnom@post.tau.ac.il

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A RETURN ON INVESTMENT ANALYSIS OF USING HEALTH INFORMATION TECHNOLOGY IN THE COURSE OF ADMISSION DECISIONS

Ben-Assuli, Ofir, Tel-Aviv University & Research Center of Ono Academic College, P.O. Box 39040, Tel-Aviv 69978, Israel, ofir.benassuli@gmail.com

Leshno, Moshe, Tel-Aviv University, P.O. Box 39040, Tel-Aviv 69978, Israel, leshnom@post.tau.ac.il

Abstract

In light of the ever-growing importance and usability of medical information systems (IS), the healthcare sector has been investing heavily in these technologies in recent years, with the aim of improving decision-making through improved medical processes, reduced costs and integration of medical data. However, these systems are extremely costly. In addition, the overall contribution of these technologies to the medical field is not obvious, especially, in high-stress environments such as emergency departments (EDs). The objective of this research is to explore whether investing in health information technology (HIT) in an ED is financially rewarding in general, and specifically the circumstances under which such an investment is more rewarding and vice versa. A cost-effectiveness analysis served as the selected tool for return on investment (ROI) estimations of certain integrative medical IS that serves seven main hospitals in Israel. We evaluated the overall profitability of this medical IS, by balancing the quality gained from information (retrieved from medical IS) against the costs of providing this information.

The results of the cost-effectiveness analysis show that our specific medical cases of chest pain received a clear cost-effective reading since the results (Δ Quality/ Δ Costs) were lower than the range of all common threshold values. Furthermore, the use of HIT in the ED improved the quality units per patient for each chosen admission decisions

The findings of this study may also contribute to policy makers in the healthcare sector regarding the advisability of investing in such systems.

Keywords: Cost-Effectiveness, Information Economy, Medical Decision-Making

1. INTRODUCTION AND MOTIVATION

The healthcare sector has been investing heavily in technologies in recent years, with the aim of improving medical decision-making through improved medical processes, reduced costs and integration of data on patients. Goldschmidt (2005) claimed that the increase in national health expenditures and the desire to improve the quality of healthcare are driving the widespread adoption of health information technology (HIT). Indeed, information retrieved by information systems can also improve the quality of the decisions made and reduce the risks and uncertainties that stem from the lack of information (Ahituv et al. 1994). By sharing real-time information, medical staff can make critical decisions resulting in safer and more efficient care. However, the new integrative medical IS are extremely costly. In addition, as the productivity paradox suggests, the overall contribution of information technologies to the field is not always immediately obvious (Brynjolfsson et al. 1996, Brynjolfsson 1993). Their impact on high-stress environments such as healthcare emergency departments (EDs), which often have to deal with an enormous number of patients under heavy time constraints, is even less obvious. The overcrowding in EDs often results in inferior clinical outcomes and reported medical errors in many aspect of emergency care, including: diagnostic errors, malfunctioning administrative procedures and wrong documentation (Fordyce et al. 2003, Hwang et al. 2004). Many of these malfunctions may have been prevented by using medical IS. Testing the contribution of medical IS is therefore a difficult and complex matter, as is estimating their return on investment (ROI). The purpose of this study was to examine the current performance of integrative medical systems and the capacity of medical IS to contribute to the field under the constraints of EDs. This purpose was accomplished by conducting a cost-effectiveness analysis of medical IS as the selected tool for ROI estimations.

2. BACKGROUND

The effects of medical information systems 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 decision-making in the stressful ED environment.

The impact of using HIT on medical decision-making has been studied in many past researches (Westbrook et al. 2005, Redelmeier et al. 1995, Lejbkowitz et al. 2004). Additionally, general implications and outcomes of HIT have been studied in order to determining diagnostic and therapeutic strategies (Shortliffe 1987, Wyatt et al. 1990) and measuring the effectiveness of triaging patients in the ED by using medical IS (Michalowski et al. 2005, Michalowski et al. 2007). Goldschmidt (2005) claims that though until recently the field of HIT has been mostly the realm of enthusiasts, and the future trends include a vision that HIT can transform the healthcare system – thereby simultaneously improving quality and productivity. He concluded that the increase in national health expenditures and the desire to improve the quality of healthcare are driving the widespread adoption of HIT but we should further research their outcomes.

There are few works that studied the financial implications and the outcomes of HIT, however, this topics are getting more academic attention only during the last years. For instance, theoretical frameworks to assess the potential value of medical information have been established only in the recent years (Claxton et al. 2005, Basu et al. 2007). Claxton (2002) and Walker et al. (2005) assessed the value of information exchange and interoperability between healthcare providers and other providers such as: independent laboratories, radiology centers and pharmacies. They showed that interoperability between these organizations would enable reduction of redundant tests, delays and additional costs. Shabtai et al. (2007) evaluated the contribution of HIT to improvement in the medical decision-making and concluded that: physicians with different expertise use different information components and that medical history of patients can improve decision-making and its outcomes.

An important issue to mention in our research is the general implications of special HIT, the electronic medical record (EMR) systems. EMRs are usually accessed via a computer, often over a network. It may be constructed of many different locations and sources. Among the many forms of data often included in EMRs are patient medical history, chronic drugs, allergy lists, laboratory test results, and billing records. Ovretveit et al. (2007) stated that there is little research and a lack of theory about implementation of EMR systems and the measurements of its financial rewording.

The literature survey leads us to various implicit and explicit recommendations for further research. One of the main avenues for further research in previous research is the economic evaluations of implementing IT in the healthcare sectors. Additionally, by following recent trends, we investigated the relationship between the use of medical IS and both of the financial and medical outcomes.

3. RESEARCH QUESTION

The objective of this research is to explore whether investing in HIT in an ED is financially rewarding in general, and specifically the circumstances under which such an investment is more rewarding and vice versa. Hence, the main research question is: *What is the ROI of integrative medical IS?*

A cost-effectiveness analysis served as the selected tool for ROI estimations of certain integrative medical IS that serves seven main hospitals in Israel. The cost-effectiveness analysis was conducted by balancing the quality gained from information regarding past medical history against the costs of providing that information. The analysis was based on the two most frequent chest pain ED cases, and compared the assessment of the results against total investments in the system.

4. METHODOLOGY

The assessment of the cost-effectiveness of our medical IS was carried out after two main stages:

- Performing an experimental study using our analytical model – We performed controlled experiments that simulate the complicated reality of an ED environment, representing the main decision process in EDs (whether to admit or discharge the patient).
- Developing a theoretical analytical model that represents the admission decision in EDs – We developed our model using medical decision trees as used by Golan et al. (2005) and Dotan et al. (2009) and as presented by Pauker et al. (1987), for evaluating the expected value of the medical IS. The evaluation of this normative value of information was based on the medical literature and on the clinical decisions made by physicians who participated in our experimental study.
- Comparing the results of the experimental study and the analytical model and conducting a cost-effectiveness using the results of the two former stages.

4.1 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 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, we chose the most common specific principal reason given by adult patients for visiting the ED, the chest pain.

¹ NCHS is the United States' principal health statistics agency. It designs and maintains a number of systems that produce data related to health concerns. 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>

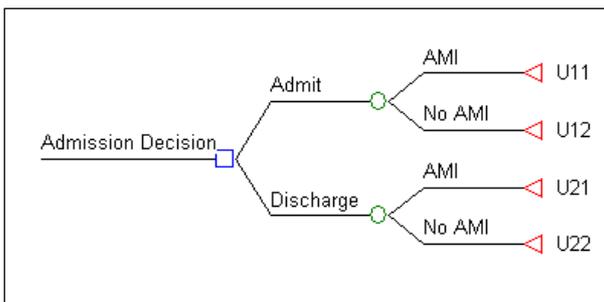
- Constructing the medical scenarios - The cases were developed by a panel of six senior physicians in cooperation with an international medical simulation center (MSR institution³) and were finalized with a pilot study. The technical data have been added to the ECFMG instructions from previous relevant researches on chest pain and on acute myocardial infraction (AMI) differential diagnosis (DD) (Goldman et al. 2003, Lee et al. 2000, Panju et al. 1998, Pope et al. 2000).
- The research took place in the form of a website-based application. The tested physician randomly received three cases with one of the following access patterns: with a full access to the medical IS or lack of any access to the medical IS. The physician decided on the medical strategy including: viewing the medical history and the physical examination, designing the diagnostic workup plan and deciding on the main DD and whether to admit or discharge the patient.

4.2 The theoretical analytical model

We begin this section with a presentation of our decision tree (most of the explanations of the calculations in the tree are not shown here in order to avoid data overload). We then provide explanations on our selected payoff approach, the general expected utility (EU) using the quality adjusted life years (QALY) measurement. Finally, we conduct the cost-effectiveness analysis.

Discussion on the use of expected utility and the threshold decision

We wish to initiate a discussion on the payoff of each alternative, by using the EU method. Figure 1 shows the main decision node of our model:



Guyatt et al. (2006) have emphasized the importance of the threshold-value approach (in accordance with Pauker et al. 1980, Pauker et al. 1987) on medical resource allocation issues. Similarly, we used one threshold probability (having the AMI disease), which represents an indifference point between admission and discharge decisions. We added a few more variable definitions as follows:

Figure 1. Admission decisions and general utilities

P - The probability of having the AMI DD. This threshold probability could be calculated by comparing the EU of admission to the EU of discharge: $E_A(U) = E_D(U)$

$E_A(U)$ - The EU of an admission decision; $E_D(U)$ - The EU of a discharge decision.

According to figure 1, The EU of admission and discharge would be calculated as follows:

Admit EU: $E_A(U) = P \cdot U_{11} + (1 - P) \cdot U_{12}$; Discharge EU: $E_D(U) = P \cdot U_{21} + (1 - P) \cdot U_{22}$

Payoff by the QALY approach using Markov model

The QALY is a measure used worldwide in the medical research field, based on the principle that a year of poor health is of lower utility than a year of life with a good health quality. QALY units are used to measure improvement in health care, while combining the predicted life expectancy with ethical values (Williams 1995). The QALY is also a common choice in decision analysis and in cost-effectiveness studies (Weinstein 2006). We will explain the impact of the QALY utilities on the medical paradox question of whether to admit or discharge a patient. We implemented the decision tree using a Markov model to estimate the differences between individuals admitted and discharged

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

from the ED, in order to simulate the long-term progression of diseases via examination of the events associated with an ongoing risk (Sonnenberg et al. 1993, Sesso et al. 2003). We included assessments of the probabilities and the outcomes of the decision tree by using this approach.

We implemented a Markov model to estimate the differences between individuals admitted and discharged from the ED. The basic assumption of these models is that each individual belongs, at any given time, to one of a finite number of health states, which allows for transitions from one health state to another during a predefined interval of time (Sesso et al. 2003). We used the model based on the possible transitions between the predefined health states outlined by Sesso et al. (2003) for the progression of cardiovascular disease (CVD) as follows: "No CVD", no history of CVD; "CVD", history of a CVD-related event. The transition from "No CVD" state to "CVD" state occurs via an event of a non fatal stroke (STRK), nonfatal AMI (MI), or via revascularization (RV). There are additional assumptions in integrating the Markov model:

- Transitions between health states occur only as depicted above. Additionally, secondary CVD-related events may occur more than once (Sesso et al. 2003, Dotan et al. 2009).
- Firstly, the probability of a secondary CVD-related event is independent of the type of preceding CVD events. Secondly, after a period of 6 months from the primary event, secondary events occur at a constant annual rate (D'Agostino et al. 2000, Sesso et al. 2003). Finally, for patients starting in the "No CVD" state and the "CVD" state, we used the data from these primary prevention studies to estimate the risk of primary CVD events, secondary CVD events and death.
- We also used the data available in major registries (Mooe et al. 1997, Rothwell et al. 2005) and in life-tables published by the NCHS (<http://www.cdc.gov/nchs>) to calibrate the rates of mortality.

Figure 2 shows the structure of the tree for the QALY analysis using Markov model.

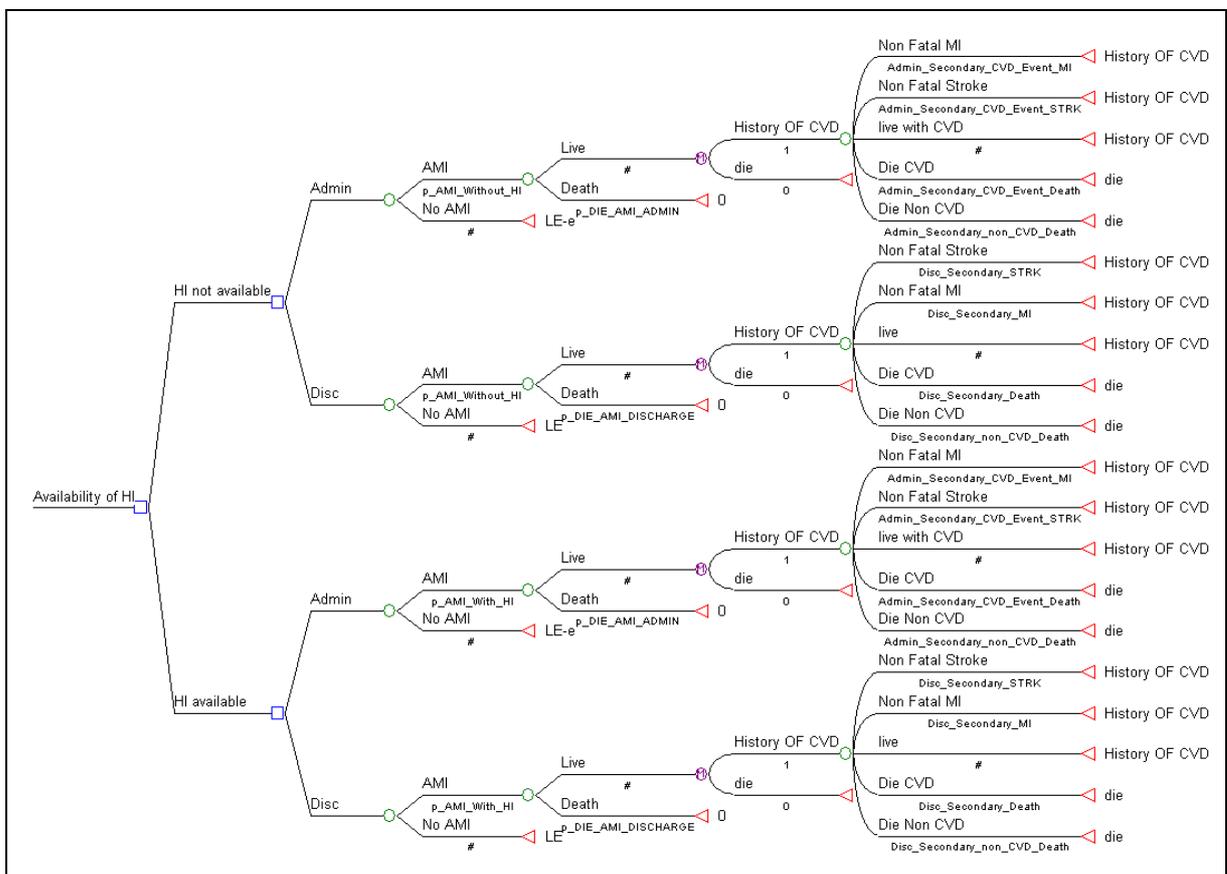


Figure 2. The decision tree using QALY Approach and Markov model

Assessments of the probabilities and the outcomes

We further clarify the related assessments of the probabilities and the outcomes that have been added to the tree as a result of the integration with the Markov Model.

The AMI probabilities:

P_AMI_With_HI: The probability in the case where the DD is AMI (D+) **when history was available** and after a negative result was obtained from **both** of the examinations used in our experiment (electrocardiogram (ECG) as T1 and cardiac enzymes (CE) as T2). Hence, the results of the post-prior probability $P(D^+|T_1^-T_2^-)$ (calculated by the following equations and the appropriate values from the experimental study) **when history was available** are:

In experiment case number 1: 9.6%. The range for sensitivity analysis: [5% - 15%]

In experiment case number 2: 2.1%. The range for sensitivity analysis: [0.5% - 5%]

These are the post prior probabilities equations:

$$P(D^+|T_1^+T_2^+) = \frac{P(T_1^+T_2^+|D^+) \cdot P(D^+)}{P(T_1^+T_2^+)} = \frac{P(T_1^+|D^+) \cdot P(T_2^+|D^+) \cdot P(D^+)}{P(T_1^+T_2^+|D^+) \cdot P(D^+) + P(T_1^+T_2^+|D^-) \cdot P(D^-)} = \frac{P(T_1^+|D^+) \cdot P(T_2^+|D^+) \cdot P(D^+)}{P(T_1^+|D^+) \cdot P(T_2^+|D^+) \cdot P(D^+) + [1 - P(T_1^-|D^-)] \cdot [1 - P(T_2^-|D^-)] \cdot [1 - P(D^+)]}$$

Letting:

$$P(T_1^+|D^+) = senT_1 - \text{The sensitivity}^4 \text{ of the T1 examination (ECG).}$$

$$P(T_1^-|D^-) = speT_1 - \text{The specificity}^5 \text{ of the T1 examination (ECG).}$$

$$P(D^+|T_1^+T_2^+) = \frac{senT_1 \cdot senT_2 \cdot P(D^+)}{senT_1 \cdot senT_2 \cdot P(D^+) + [1 - speT_1] \cdot [1 - speT_2] \cdot [1 - P(D^+)]}$$

And in a similar way:

$$P(D^+|T_1^+T_2^-) = \frac{senT_1 \cdot (1 - senT_2) \cdot P(D^+)}{senT_1 \cdot [1 - senT_2] \cdot P(D^+) + [1 - speT_1] \cdot speT_2 \cdot [1 - P(D^+)]}$$

$$P(D^+|T_1^-T_2^+) = \frac{(1 - senT_1) \cdot senT_2 \cdot P(D^+)}{[1 - senT_1] \cdot senT_2 \cdot P(D^+) + speT_1 \cdot [1 - speT_2] \cdot [1 - P(D^+)]}$$

$$P(D^+|T_1^-T_2^-) = \frac{(1 - senT_1) \cdot (1 - senT_2) \cdot P(D^+)}{[1 - senT_1] \cdot [1 - senT_2] \cdot P(D^+) + speT_1 \cdot speT_2 \cdot [1 - P(D^+)]}$$

P_AMI_Without_HI: The probability in the case where the DD is an AMI (D+) **when history was not available** (after a negative result was obtained from both of the examinations (ECG as T1 and the CE as T2) in experiment case # 1, and, when a positive result was obtained from the ECG examination and a negative result was obtained from the CE examination in experiment case # 2). Hence:

In case 1: the post-prior probability $P(D^+|T_1^-T_2^-)$ derived from the calculations of equations shown above, when history was **not** available is: **0.5%**. The range for sensitivity analysis: [0.1% - 5%].

⁴ Sensitivity of medical examination - The sensitivity measures the proportion of actual positives which are correctly identified in the medical examinations (i.e. the percentage of sick people who are identified as having the condition).

⁵ Specificity of medical examination - The specificity measures the proportion of negatives which are correctly identified in the medical examinations (i.e. the percentage of healthy people who are identified as not having the symptoms).

In case 2, the post-prior probability $P(D^+|T_1^+T_2^-)$ derived from the calculations of equations shown above, when history was **not** available is: **38.7%**. The range for sensitivity analysis: [30% - 46%].

P_Die_AMI: The probability of a death of a patient within 30 days in the case where the DD is AMI (D+). In our study this probability has two options that are derived from the admission decision: P_Die_AMI_Admin and P_Die_AMI_Discharge:

P_Die_AMI_Admin - The probability of a death of a patient within 30 days in the case where the DD is AMI (D+) **when a decision to admit was made**.

We chose to adopt a mortality ratio within 30 days from Pope et al. (2000)'s large data set which was appropriate and in the range of mortality rates of other studies as well. We set the P_Die_AMI_Admin to **5.7%**. The range for sensitivity analysis: [3.5% - 7.9%].

P_Die_AMI_Discharge - The probability of a death of a patient within 30 days in the case where the DD is AMI (D+) **when a discharge decision was made**.

We used the previous research that explored the relationships between the two derived probabilities of P_Die_AMI, since the direct probability without using this relationship was very difficult to find in the literature. The risk-adjusted mortality ratio amongst discharged patients with AMI is about twice (1.9) as much as the risk-adjusted mortality ratio amongst admitted patients with AMI within 30 days (Pope et al. 2000). Consequently, we set the P_Die_AMI_Discharge to **10.83%** ($2 * P_Die_AMI_Admin = 5.7\% * 1.9$). The range for sensitivity analysis: [8% - 14%].

The Markov model probabilities and outcomes

The rates used in our model (edited in table 3 below) were extracted from many clinical studies listed in the Meta analysis made by Dotan et al. (2009). During the simulation (i.e, at runtime), we converted these rates to probabilities by using the method described by Disch et al. (1994), in the form of triangular distributions, to generate probabilities within the Monte Carlo simulations, as proposed by Hunink et al. (2001). Table 3 below shows these event rates computed at runtime according to a triangular distribution and a decreasing life expectancy.

The outcomes are consisted of the utilities in QALY units (to measure the "effectiveness"). Table 3 (below) represents the utilities in QALY units per year (ranging from 0 – death until 1 – healthy lives). QALY values were computed according to the procedure described by Muennig et al. (2001): using the accepted preference scores catalogue "The Cost-effectiveness Analysis Registry" (CEA⁶).

The cost-effectiveness analysis was performed in our study by balancing the QALY units gained as the beneficial effect of admission decision according to the disease conditions against the expected costs (Gudex et al. 1988, Pliskin et al. 1999, Golan et al. 2005, Guyatt et al. 2006) and by using a Markov model (Shamir et al. 2006, Leshno et al. 2003). The only missing part for performing such analysis is the details about the costs:

The evaluation of the costs associated with admission decisions

In general, acute care costs include hospitalization and any other related services such as ambulance, physician services, and rehabilitation costs, ordering and performing medical tests. In all of the medical scenarios we did not include the administrative referral costs. In order to properly evaluate the additional costs in US Dollars per year, we used secondary data from several recent studies (Fitch et al. 2007, Caro et al. 2007, Heeg et al. 2007, Grines et al. 1998) and we used a second assessments of experts and price-lists from the Israel Ministry of Health on this data from the studies mentioned above. These costs per first year including derived operations for each admission decision are presented in table 3 below with a wide range for sensitivity analyses.

⁶ See at: <https://research.tufts-nemc.org/cear/Default.aspx>

5. FINDINGS

5.1 The Experimental Study

The experiments were performed on 102 real physicians. Dealing with real practical decision-makers increases the external validity (Jarvenpaa et al. 1985). 53 physicians were provided with an access to the medical IS and 49 physicians were not provided with an access to the medical IS in the experiments. The difference in the number of physicians with and without access to the medical IS is due to the random access patterns of the medical IS. In general we had three simulated cases:

- In case number 1, without any additional information from the medical 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 medical 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 number 2, without any additional information from the medical 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 from the medical 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 number 3, which serves as a control case, in both cases (with or without additional information from the medical 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. Case no. 3 was verified to serve as a control case in our results and is not shown here in order to avoid data overload.

The term "medical history" below concerns to the additional information gained from the medical IS only for physicians who received an access to it. For other physicians, they were exposed only to the major complaint and to the limited demographic data which were equally provided to all the participants. We compared the number of admission decisions made by the physicians, of patients with medical history which was not viewed, and patients with medical history which was viewed.

Percentage of Admissions when Medical History Was Not Viewed	Percentage of Admissions when Medical History Was Viewed	Increase in Admissions ⁷	p-value
36.7% (18 physicians)	88.7% (47 physicians)	142.7%	<0.001

Table 1. Case 1: Comparing proportions admission rates

Percentage of Admissions when Medical History Was Not Viewed	Percentage of Admissions when Medical History Was Viewed	Decrease in Admissions	p-value
87.8% (43 physicians)	56.6% (30 physicians)	35.54%	<0.001

Table 2. Case 2: Comparing proportions admission rates

Summary of the main findings:

A review of medical history contributes to admission decisions. Not only does it clearly reduce the number of unnecessary admissions (case 1), but it also increases the necessary admissions (case 2). In addition, the experiment results supported our theoretical results (in section 5.2) by supplementing statistical significance

⁷ The result of 36.7% represents the number of physicians who had an admission decision in case 1, when medical history was not viewed (18) as a percentage of all participated physicians when medical history was not viewed in case 1 (49). And as a result: $18/49=36.7\%$. The increase in the admissions rate is calculated as the difference in the percentage of admissions between the situations without and with view of medical history. And as a result: $(36.7\%-88.7\%)/36.7\%=142.7\%$.

5.2 The cost-effectiveness ($\Delta QALY / \Delta COSTS$)

In this section, we firstly show the variable values including the range for sensitivity analyses and secondly, we compare the results (in a manner of QALY units) between the two admission decisions (admit and discharge). Finally, we test the correspondence between our QALY results and the statistical empirical results in the experiment (shown above). We focused on the branch with the availability of information via the IS, although in figure 2, we also showed the other branch (without access to the medical IS). Here are the variable values including the range for sensitivity analyses:

Variable	Definition	Value	Range for sensitivity analysis
P_AMI_With_HI	The probability of having AMI when History was available	Case 1: 9.6% Case 2: 2.1%	Case 1:[5% - 15%] Case 2:[0.5% - 5%]
P_AMI_Without_HI	The probability of having AMI when History wasn't available	Case 1: 0.5% Case 2: 38.7%	Case 1:[0.1% - 5%] Case 2:[30% -46%]
P_Die_AMI_Admin	The probability that the patient dies within 30 days after having AMI when a decision to admit was made	5.7%	[3.5% - 7.9%]
P_Die_AMI_Discharge	The probability that the patient dies within 30 days after having AMI when a decision to discharge was made	10.83%	[8% - 14%]
Markov Model: Primary and Secondary CVD (expressed in terms of annual events per 1000)			
Non-CVD death (Primary CVD)		7.18	1.11 – 13.25
CVD death (Primary CVD)		2.4	0.26 – 4.55
Myocardial infarction (MI) (Primary CVD)		1.45	0.18 – 2.72
Nonfatal stroke (Primary CVD)		1.15	0.87 – 1.43
Revascularization (Primary CVD)		0.78	0.37 – 1.19
Non-CVD death (Secondary CVD)		10.98	6.06 – 15.91
CVD death (Secondary CVD)		15.32	11.38 – 19.26
Myocardial infarction (MI) (Secondary CVD)		11.77	9.08 – 14.46
Nonfatal stroke (Secondary CVD)		8.67	7.85 – 9.5
Markov Model: Utility (in QALY units per year)			
The patient Admitted or discharged and died		0	-
Discharge decision after Non-AMI DD		1	-
Admission decision after Non-AMI DD (redundant)		0.999	0.998 - 1
The patient Admitted or discharged after Non-AMI DD and lived (in QALYs per year in Markov Model)			
History of MI		0.7	0.5 – 0.7
History of Stroke		0.4	0.2 – 0.7
History of both Stroke and MI		0.29	0.14 – 0.43
The additional costs in US Dollar per year used (including admissions and derived operations)			
Costs when an 'admit' decision was made after AMI DD		15,000\$	5,000\$ – 20,000\$
Costs when an 'admit' decision was made after non-AMI DD (redundant)		500\$	300\$ - 1,000\$
Costs when a 'discharge' decision was made after AMI DD		8,250\$	2,750\$ – 11,000\$
Costs when a 'discharge' decision was made after non-AMI DD		0\$	-

Table 3. Variable Values and Sensitivity Analysis

For the analysis of the experiment results, we used the "TreeAge Pro" program in order to analyze the decision tree (shown in figure 2) with the outcomes QALY units and with the costs.

Findings from case 1:

- The additional QALY units per admitted patient (justified) to the hospital resulting from review of medical history are measured as the difference between the decision to admit and the decision to discharge, resulting in: $22.2611 - 22.2008 = 0.0603$ QALY units. These findings correspond, in the dominancy of admission decision, with the findings of the experimental study. The results of our sensitivity analysis further validate our findings due to many changes in our variables including Monte Carlo simulation on 100,000 trials (average Δ QALY=0.064). Meaning that the use of medical IS during the period of treatment in the ED improves the QALY units per patient.
- The additional costs per admitted patient to the hospital resulting from review of medical history were measured as the difference between the decision to admit and the decision to discharge resulting in: $1,904.43\$ - 792\$ = 1,112.43\$$. The more costly option is to admit the patient as expected.

Admission Decision	QALY Per patient (Life-Expectancy)	Costs Per patient (\$)	Δ QALY Per patient	Δ C Per patient	Δ C/ Δ QALY
Admit	22.2611 years	1904.43\$	0.0603	1112.43\$	1112.43\$/0.0603 =18448.26\$
Discharge	22.2008 years	792\$			

Table 4. Case 1: Cost-Effectiveness Analysis

Findings from case 2:

- The additional QALY units per discharged patient (justified) from the hospital resulting from review of medical history are measured as the difference between the decision to admit and the decision to discharge resulting in: $32.615 - 32.610 = 0.005$ QALY units. These findings also correspond, with the findings of the experimental study. The results of the sensitivity analysis further validate our findings including Monte Carlo simulation on 100,000 trials, which yielded similar results (average Δ QALY=0.007). Meaning that the use of medical IS during the period of treatment in the ED improves the QALY units per patient.
- The additional costs per discharged patient resulting from review of medical history were measured as the difference between the decision to admit the patient and the decision to discharge the patient resulting in: $185.68\$ - 804.5\$ = -618.82\$$ (saving 631.25\$). The least costly option is to discharge the patient, meaning that the discharge decision in this case using the medical IS is the most optimal.

Admission Decision	QALY Per patient (Life-Expectancy)	Costs Per patient (\$)	Δ QALY Per patient	Δ C Per patient	Δ C/ Δ QALY
Admit	32.615 years	185.68\$	0.005	-618.82\$	Cost-Saving
Discharge	32.610 years	804.5\$			

Table 5. case 2: Cost-Effectiveness Analysis

Discussion on the cost-effectiveness analysis results

The main question is: what the affordable cost threshold value is made for adoption of medical IS. In general, in strategic policy decision-making in the healthcare sector there are accepted rules in health economics policies as explained here below. According to Medicare⁸ organization, any investment in medical accessory, medicine or treatment which led to improvement has a cost-effectiveness threshold of 50,000\$ for gaining one QALY unit per patient (below 50,000\$ it is very cost-effective). The

⁸ See at: <http://www.medicare.gov/>

standard practice of Medicare is not a comprehensive practice but rather a minimal threshold for benchmark values. Many studies and organizations have set higher threshold values for which medical intervention is financially justifiable (such as: Hirth et al. 2000, Devlin et al. 2004). According to the World Health Organization⁹ (WHO), an intervention is considered to be (all monetary values are in 2008 values in Israel):

- Cost-Saving: if treatment costs averted exceed intervention costs.
- Very Cost-Effective: if costs per QALY saved \leq per capita GNP (around \$27,000).
- Cost-Effective: If costs per QALY saved $\leq 3 \times$ per capita GNP (around \$81,000).
- Not Cost-Effective: If costs per QALY saved $> 3 \times$ per capita GNP (around \$81,000).

Our results varied in both of the medical cases. In case 1, the additional costs per patient per one QALY unit as a result of using integrative medical IS is 18,448.26\$ (**very cost-effective**), and in case 2, the **saved** costs per patient per one QALY unit as a result of using integrative medical IS is 618.82\$ (**cost-saving**). Consequently, in our study, both of our special medical cases of chest pain received a clear cost-effective reading, since the results were lower than the range of the threshold values. Hence, in our specific cases, the investment in our integrative medical IS seems to be financially worthwhile.

6. CONCLUSIONS

Our findings lead to these major conclusions:

- Investing in an integrative medical IS is financially worthwhile (cost-effective and even cost-saving), provided that medical history was supplied to the physicians at the point of care of an ED during the triage of the patients in our specific cases of chest pain formulated in our experiments.
- The use of integrative medical IS during the period of treatment in the ED improves the QALY units per patient for each chosen medical decisions.

7. CONTRIBUTION AND LIMITATIONS

The main purpose of our research was to contribute to scientific knowledge by providing additional insight into the various fields such as: information economics. We enumerate two main contributions:

- Review of medical history contributes to admission decisions. This contribution was discovered both in the theoretical normative model and also in the course of an experimental study.
- Proving cost-effectiveness for the use of integrative medical IS by using a Markov model and investigating the famous productivity paradox (Brynjolfsson et al. 1996, Brynjolfsson 1993) in the healthcare sector.

The findings of this study may also contribute to policy makers in the healthcare sector regarding the advisability of investing in such systems and managing them.

It is important to note the limitation that our findings related only to our specific experimental cases, which represent accepted and very frequent scenarios in the medical literature. However, these theoretical cases are quite limited in the generalization option. Hence, although we believe our results are valid, further research is advisable on this subject.

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⁹ The WHO is an international commission on macro economics and health. See at: <http://www.who.int/en/>.

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