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Improving diagnostic accuracy using EHR in emergency departments: A simulation-based study

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ABSTRACT

It is widely believed that Electronic Health Records (EHR) improve medical decision-making by enabling medical staff to access medical information stored in the system. It remains unclear, however, whether EHR indeed fulfills this claim under the severe time constraints of Emergency Departments (EDs). We assessed whether accessing EHR in an ED actually improves decision-making by clinicians. A simulated ED environment was created at the Israel Center for Medical Simulation (MSR). Four different actors were trained to simulate four specific complaints and behavior and 'consulted' 26 volunteer ED physicians. Each physician treated half of the cases (randomly) with access to EHR, and their medical decisions were compared to those where the physicians had no access to EHR. Comparison of diagnostic accuracy with and without access showed that accessing the EHR led to an increase in the quality of the clinical decisions. Physicians accessing EHR were more highly informed and thus made more accurate decisions. The percentage of correct diagnoses was higher and these physicians were more confident in their diagnoses and made their decisions faster.

1. Introduction

In recent years, the healthcare sector has invested widely in state-of-the-art medical technologies to improve medical decision-making. These technologies have prompted much research [1–3] aimed at improving the quality and efficiency of health services through health information technology (HIT). Most studies, however, have focused on the commercial aspects of the system [4]. The assumption is that HIT will improve medical processes and reduce costs through the integration of patient data and their immediate accessibility to physicians and medical staff. Studies have shown that Electronic Health Records (EHR) a widely used version of HIT, can improve physicians' performance and quality of care [5–8]. Although physicians can reach valid, reasonable conclusions regarding medical treatment despite imperfect information [9], without an easy access to a full medical history, they may make poor decisions.

Medical history retrieved by EHR allows physicians to have a more comprehensive view of the patient. Providing extensive information and care options can simplify decision complexity in numerous medical situations [10]. Meaningful HIT use is thought to lead to: (1) improved quality, safety, efficiency of care; (2) better engagement with patients and families; (3) improved care coordination; (4) better population and public health; and (5) greater privacy and security [3]. These advantages should lead to clear critical informative decisions. However, the impact of EHR on high-stress environments such as emergency departments (EDs), which often have to deal with overcrowding and heavy time constraints may curtail these advantages. In particular, the overcrowding in EDs often results in inferior clinical outcomes [11–15] diagnostic errors, wrong documentation, and wrong pharmacotherapy [16,17] as well as poor exploitation of the EHR [18]. Although availability of medical information is crucial to the success of medical care [19–21] in the ED, physicians' access to the system is often limited [22].

2. Implementation of integrated systems and medical decision-making

The impact of using integrated medical information systems on medical decision-making has been investigated in numerous studies [10,23–27]. The general implications and outcomes of HIT have

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been explored to determine diagnostic and therapeutic strategies and planning resources [28–30] and to measure the effectiveness of triaging patients in the ED through medical information systems [31]. Many factors influence decision-making including conditions of uncertainty and risk [32], heuristics [33], and experience [34]. Studies on the influence of medical systems on decision-making in real time have shown that clinicians are interested in accessing data aggregated in terms of demographics, tests, procedures, and treatments, and in particular, the results of the same diagnosis [35]. Physicians are required to make constant decisions during their daily workflow such as diagnosis, therapeutic interventions, involvement of other physicians and so on. To manage information and decision-making clinicians can use HIT [36]. EHR stores patients' information in an organized accessible manner (unlike paper charts that can be dispersed and easily misplaced), but at times can impede the regular flow [37].

Ben-Assuli et al. [11,38] analyzed the effect of EHR use on medical decision-making and showed that EHR use can improve decision-making and may enhance medical efficiency. The use of management guiding strategies (such as the Plan-Do-Study-Act model) can improve the performance of medical staff and help overcome the challenges of implementation [39]. The confidence of decision-makers and the time taken to make these decisions are also underlying elements in the decision process. It has been shown that in general, a clinical support system can efficiently triage patients using a limited amount of information [28,40,41], and can result in both clinical and economic advantages.

Physicians' confidence also has considerable impact, especially in stressful environments where physicians must make life-saving decisions. Interactions with colleagues have been found to increase decision-makers' confidence [42], presumably because they provide additional information that supports the decision. In addition, exposure to information related to a specific course of action influences decisions by increasing the level of confidence [43]. In instances when medical history is available and viewed, clinicians may have more confidence, which allows them to make more effective decisions with lower uncertainty-related biases [44]. Though physicians state they have a high level of confidence after receiving information [24,45] exposing them to additional information and therapeutic options has been shown to increase decision complexity in several medical situations [10].

In terms of the implementation of integrated medical information systems, Black et al. [46] pointed out that the inexorable increase in national health expenditures and the desire to improve the quality of healthcare are spearheading the widespread adoption of HIT but their outcomes should be reviewed and researched. Only a few studies have been conducted to better define a theoretical framework to assess the potential value and cost effectiveness of HIT [38,47,48] More specifically, Claxton et al. [49], Walker et al. [19] and Kapoor & Kleinbart [50] found that electronic healthcare information exchange (HIE) and interoperability between healthcare providers can save costs to health maintenance organizations (HMOs).

An HMO is an organization that provides health care services to the insured individuals and connects them with health care providers (such as hospitals, physicians, and community care) on a prepaid basis. This type of organized care has been found to reduce hospitalization costs for care [51] and increase satisfaction among patients [52]. Medical care provided in such an environment is comprehensive (since the HMO owns many facilities and services in most branches of medicine) and thorough (many physicians and medical staff communicate and create holistic therapeutic care plans).

Technology acceptance is another critical factor that has received attention in empirical studies on the healthcare sector [53,54]. The findings suggest that the integration of HIT in health care facilities is not without pitfalls. Many factors appear to affect rejection including IT resistance [55], incorrect measurement methodologies [56] and misguided expectations from the IT [57]. Two of the most important design principles that have emerged as regards reinforcing acceptance are identifying users' needs, and incorporating workflow integration [58]. An additional element in HIT is the specific needs of health care professionals from different fields [59]. For example, psychiatrists need further information such as prescription compliance and/or abuse and additional functions within the system such as wireless patient monitoring [60]. Pediatricians, on the other hand, check for growth parameters and might need the system to calculate a development curve [61–63].

3. The current study

Healthcare organizations use different kinds of local and external computerized HIT systems to manage medical care and support decision-making. In Israel, full patient medical records are in various phases of assimilation. The current study examined "OFEK", a specific interoperable EHR system which enables direct access to patients' medical information as recorded by multiple healthcare providers in both hospital and community settings (Appendix A). Currently, OFEK is implemented in all hospitals in Israel and all health institutes owned by Clalit HMO, the largest Israeli HMO with more than three and a half millions customers.

Both clinical and non-clinical factors influence medical decision-making, especially in the ED [64]. Our main goal was to examine the impact of the OFEK EHR on clinical decision-making and its contribution to the clinical decision-making of ED physicians, and especially the accuracy of diagnoses. The study was conducted at the Israel Center for Medical Simulation (MSR) (http://www.msr.org.il/e). MSR is a national resource for simulation-based training and assessment where multiple studies have been conducted on the effectiveness of simulations in improving health professionals' clinical proficiencies, including studies in the challenging area of doctor-patient computer skills, where health professionals encounter simulated patients (SPs) in an authentic simulated environment that includes their customized EHR and receive feedback on their communication skills in this setting [65–67].

The use of simulation as a research method in empirical studies on EHR nevertheless remains the exception to the rule. A previous study investigating genetic testing using an EHR simulation reported a positive impact [68]. Another EHR simulation revealed security faults in an EHR system [69]. Borycki et al. [61] used a simulated EHR environment in order to demonstrate its ease of use to physicians and to overcome barriers to EHR adoption. Hammond et al. [62] created a simulated environment and found that physicians tend to use more paper than electronic means. Others have shown that genetic testing and information can be incorporated into the system [63]. However few studies have used simulation to evaluate the effect of EHR on clinical decision-making. Hence, this research addresses some of the gaps in previous research, which has dealt with similar issues but considered many other goals including the implementation of technology for the triage of patients in EDs [31] and the implementation of EHR for assisting to the diagnosis accuracy and the admission decisions [44,70].

4. Research objective and hypotheses

The main objective of the current study was to assess EHR use and examine whether it improves medical decision-making during ED triage. The EHR system makes patients' medical history available to the medical staff, which in the past (or in current facilities not using HIT) took considerably more time to obtain.

We studied whether presenting more information in a rapidly accessible manner would have a beneficial effect on medical decision-making and therapeutic interventions. We formulated four hypotheses accordingly.

Recently, many studies have discussed using a checklist when diagnosing patients [71,72], and some have even suggested incorporating one into the EHR system [73]. We formulated the following hypothesis:

H1. There is a positive relationship between the use of EHR and increased diagnostic accuracy.

Traditionally, medical histories were almost always obtained through medical interviews. Clearly, the more information there is about a certain patient, the better the decision and diagnosis the physician can make [74]. Previous studies have reported a significant association between EHR use and better medical care (such as cancer screening and diabetes testing) [75].

Previous research suggests that EHR can facilitate justified admission and discharge decisions [44,70]. Justified admissions refer to a medical situation in which the patient's condition requires admission to one of the units in the hospital. Justified discharges refer to a situation where the physician determines that the patient's condition does not require hospitalization and can be treated at community clinics. Therefore:

H2. There is a positive relationship between the use of EHR and making an accurate admission decision. Access to EHR should lead physicians to:

H2.1. Make more justified admissions to the hospital.

H2.2. Make fewer unjustified admissions to the hospital (more justified discharges).

An informed medical decision that relies on both current symptoms and medical history (which can be obtained from the EHR) should be founded and substantial. Additional information such as the community physician's opinions, lab tests and other physiological parameters can assist physicians in making accurate decisions and can also increase their confidence. Under such conditions, physicians are more likely to work more effectively, provide better care in less time [76]. Hence:

H3. There is a positive relationship between the use of EHR and the confidence of the decision-maker regarding the choice of future management and diagnostic actions for the patient.

Physicians in the ED often do not have enough time to wait for test results [77]. Even in situations when the medical information is crucial, physicians are sometimes forced to make fast decisions without test results [78]. Thus, the EHR system might save time [79] by providing medical staff with access to existing tests, physicians' opinions and other information entering into the diagnostic process. It has also been found to save time in terms of the administration workload [80]. Consequently:

H4. There is a negative relationship between the use of EHR by physicians and time to reach diagnosis.

5. Methodology

5.1. The experiment and medical scenarios

We observed the performance of 26 physicians in four simulated cases for a total of 103 simulated cases (four cases for each physician; one physician could only participate in only three cases).

The groups was made up of ED residents and senior physicians, and internal medicine residents who also work at the ED. The cases were all frequent ED scenarios, chosen from among the most common clinical scenarios at the National Center for Health Statistics (NCHS), the principal health statistics agency in the US. These cases also appear in the textbooks of the Educational Commission for Foreign Medical Graduates (ECFMG), which assesses the readiness of international medical graduates to enter residency or fellowship programs in the USA. The scenarios were developed by senior physicians from Sheba Medical Center's ED and MSR. This institution has many years of experience in the field of simulation and training with simulations. The scenarios were all based on real cases. All four scenarios, symptoms, and test results made available to the participants are described in detail in Appendix B, including the rationale for each case (two cases dealt with chest pain complaints and two with abdominal pain). All scenarios had a gold standard, a clear desired outcome and a clear differential diagnosis. Along with these standards, from a clinical and therapeutic point of view, some diagnoses (made by the participating physicians) were the most accurate, but additional diagnoses could also be appropriate and were, in fact, defined as correct as well. For example, in 'Chest Pain – Scenario A' the appropriate diagnosis was acute coronary syndrome. However, musculoskeletal chest pain was a fairly reasonable diagnosis as well, though not as accurate as acute coronary syndrome. In two scenarios (Chest Pain – Scenario B and Abdominal Pain – Scenario A), the information from OFEK supported the decision to discharge the patient despite conflicting clues from the medical interview and medical tests. In one scenario (Abdominal Pain – Scenario B), information from OFEK supported an admission decision despite information provided from the SP and additional tests. In the final scenario (Chest Pain – Scenario A), the admission decision was the expected decision with or without using OFEK. We planned this scenario to serve as a control, to assess whether participants would automatically change their decision after exposure to information from OFEK EHR.

The scenarios were presented by SPs in a mock ED room at MSR. Each one of the four simulated cases was presented by the same actor in all observations (to prevent bias). The actors were professionals trained to simulate patients in many training and examination projects at the Center, and were experienced in simulating various symptoms.

In order for the simulation to be similar for all participants, the SPs were trained to fully simulate an emergency case including high stress levels during their examinations, and provide answers that would be expected from an ED patient. They were trained to present the same symptoms and to answer uniformly in the medical interview to keep the clinical picture constant for all participants. Each SP had a list of physiological indices to match their illness in addition to the symptoms they were asked to portray. Like any regular ED patient, the SPs gave information if asked but could not always remember their previous tests, diagnoses or findings in detail. The entire sequence of the study (including different test results) was carefully planned by the group of experienced medical professionals.

Prior to the simulation, the participating physicians received a brief description of the experiment. They were aware that the situation was a simulation and that the patients were in fact actors. The participating physicians were able to examine the actor-patients (by asking any question they wanted about their physical condition and receiving full answers). In the first phase of the experiment, the physicians interviewed the SPs, took their history, and examined them with no time limitations. In the second phase, they were asked to state their preliminary differential diagnosis and their level of confidence in it. Following this phase, they could order medical tests. Pre-prepared results were given to them on request. Physicians with access to OFEK EHR were able to view the patient's additional medical charts (visits to other hospitals and community information, etc.) at this phase. In the last phase, the physicians were asked to state their final diagnosis and to decide whether to admit or discharge the patient (they could also add further management strategy and a diagnostic workup plan).

This study was designed to simulate an ED. We could not fully simulate the chaotic and stressful ED environment, but we did simulate common cases, distressed and challenging patients, time constraints and common ED workflow. The participating physicians were all volunteers who took part in the study during their work hours in the real ED/internal wards. They were all excused in the middle of their shift for the simulation study, and were expected to return as soon as possible. Therefore they were in an "ED mindset" and treated the SPs as part of their daily routine in the ED. We did not introduce any other artificial interruption or distraction. As in real life, the physicians had no inherent time limit for the medical encounter, but could return to their daily work if necessary. They could then come back to examine the SP at any time during the simulation (and indeed, two physicians did so).

To compare the decision-making of physicians who had access to complete clinical information (via the OFEK EHR system) and those without access we equipped the simulated environment with the OFEK system (the commercial version), including mock medical files for the SPs. Access was available just after the medical interview and prior to their preliminary diagnosis.

For each scenario, the EHR contained test results (such as CTs and blood tests) reflecting the specific illness presented by the SP (for example, in chest pain-scenario B, the EHR system contained a chest X-ray, an ECG and a recent discharge letter from another hospital). Note that access to data did not necessarily imply access to useful information.

5.2. Independent variables

5.2.1. EHR use

Each physician had access to EHR in two of the cases (randomly), and no access in the other two. This variable was coded as dichotomous (1 = Full access to EHR/0 = No access). The system was the commercial version of OFEK. All participants had used the system previously. Background medical information was "planted" in the EHR. Physicians had access to this information by entering the SP's simulated ID number. In this experiment, we did not include all of the SPs' history in OFEK and restricted it to general health information and history applicable to the simulations.

5.2.2. Seniority status

Based on previous studies that have reported differences in the decision-making processes of professionals depending on status [81–83] the physicians' seniority was analyzed (1 = senior physicians/0 = residents).

5.2.3. Specialty

Based on studies that have reported differences among the information components used by physicians with different specialties, the physicians were classified according to their specialty (internal medicine vs. emergency). Internists were coded as 1 and the emergency physicians as 0.

5.2.4. Familiarity with the tested EHR

To control for different levels of familiarity with the EHR used in this study, this variable assessed level of familiarity with the system (on an odd Likert scale of 1–9).

5.2.5. Years of general experience with EHR

To control for different levels of experience in the use of any EHR, this variable represented the actual years of general experience with any EHR.

5.3. Dependent variables

The participants filled in their initial and final diagnosis, admission decision, and confidence level in a questionnaire provided to them. We used open-ended questions for diagnoses with yes/no check boxes for admission decisions and a Likert scale to assess confidence level.

5.3.1. Differential diagnosis

This variable represents the diagnosis made by the physician for each case (according to diagnostic standards of the ICD10)

5.3.2. Admission decision

This variable represents the physician's decision to admit (coded 1) or discharge (coded 0) the patient.

5.3.3. Confidence level

This variable evaluated the effect of the use of EHR on confidence level (the strength of belief in the accuracy of diagnosis and decisions) of the decision-maker. It was formulated as an odd Likert scale ranging from 1 to 7 (7 = highest confidence level). We tested this variable twice: before physicians ordered tests and after.

5.3.4. Time

This is known to be a factor of significant influence on decision-making [83–87], especially in EDs. This variable was measured in minutes, representing the amount of time each physician needed to handle the case. The measurement included the time physicians took to check the SP (including all medical stages).

6. Results

6.1. Descriptive statistics

The group of twenty-six physicians was made up of 15 internists and 11 emergency physicians (7 seniors and 19 residents). The sample consisted of a relatively equal proportion of men and women, with a higher proportion of internists (compared to ED physicians). Most of the sample consisted of residents, with a substantial variability in terms of years of experience. The percentage of residents represented the proportion of residents in the real EDs in the hospital; namely, most physicians in the ED are residents and not senior physicians. Most of them rated their level of EHR use around the middle range of the scale. Table 1 lists the demographics of the participating physicians.

6.2. Impact of using EHR on differential diagnosis

In 'Chest-pain scenario A', it could be claimed that neither of the two main diagnoses constituted a medical error. The most appropriate diagnosis was acute coronary syndrome and in fact, EHR use increased the rate of this diagnosis. However, musculoskeletal chest pain was also appropriate, though not as accurate as acute coronary syndrome. Given the patient's medical information stored in the EHR physicians were probably unable to rule out this diagnosis. However using EHR was associated with a significant improvement in diagnosis accuracy (see Table 2).

Table 1
Participants' demographics.

Measure	
Age mean (SD)/range	36.42 (3.95)/30–45
Gender (%)	Males-12 (46.15%)/ Females-14 (53.85%)
Specialty (%)	Internal medicine-15 (57.69%)/emergency-11(42.31%)
Seniority (%)	Seniors-7 (26.92%)/ residents-19 (73.08%)
Years of experience as a physician Mean (SD)/Range	3.75 (3.26)/1–13
Level of EHR use mean (SD)/range	4.89 (2.37)/1–9
Years of experience with any EHR[a] mean (SD)/ range	4.35 (2.39)/0–10

[a] *Note*: On an odd Likert scale of 1–9.

Table 2
Chest pain-scenario A – differential diagnosis.

Diagnosis	Preliminary diagnosis percentage$^+$ (number of physicians)		Final diagnosis percentage* (number of physicians)	
	No EHR used	EHR used	No EHR used	EHR used
Acute coronary syndrome	33.3% (4)	76.9% (9)	16.7% (2)	61.5% (8)
Musculoskeletal chest pain	50.0 (6)	15.4% (2)	66.7% (8)	38.5% (5)

Note: Data do not sum up to 100% due to cases in which neither of the above diagnoses was made. Preliminary diagnosis was made prior to testing, in the ED, and Final Diagnosis was made after receiving test results. $^+p < 0.1$ $^*p < 0.05$ $^{**}p < 0.01$ $^{***}p < 0.001$ $^{n/a}$Not applicable (similar conventions appear in the tables below).

In 'Chest pain scenario B', no access to the EHR system led to dissection of aortic aneurysm as the most likely diagnosis, whereas using EHR provided data on previous tests that made musculoskeletal chest pain a more reasonable choice. Without access to the EHR, 66.7% of the participants diagnosed aortal dissection, and none diagnosed musculoskeletal chest pain, whereas using EHR, 57.1% of the participants diagnosed musculoskeletal chest pain, and only 14.3% diagnosed dissection of aortic aneurysm (Table 3).

In 'Abdominal pain scenario A', the correct diagnoses were either irritable bowel syndrome (IBS) or gastroenteritis. Table 4 shows that using EHR improved diagnosis accuracy by increasing the rate of diagnosing IBS to 92.9% (compared to 58.3% without using EHR), together with 7.1% diagnoses of gastroenteritis.

In 'Abdominal pain scenario B', without using EHR the expected diagnoses would have been nephrolithiasis and radiculitis. As expected, these were the two most frequent diagnoses in this case (Table 5). However, using EHR revealed a previous abdominal CT scan, indicating a likely diagnosis of abdominal aortic aneurysm. Table 5 shows that the rates of this diagnosis increased significantly by several percent, alongside a decrease in diagnosing radiculitis in the case of EHR use.

6.3. Impact of using EHR on admission decisions

The impact of EHR use on admission decisions varied as a function of the case. This variability was expected, given the nature of the cases and differences in medical information which suggested different clinical strategies. For instance, in 'Chest pain scenario A', EHR use increased admission rates, whereas in 'Chest pain scenario B', EHR use dramatically reduced admissions (see Table 6 for all scenarios).

Table 3
Chest pain scenario B – differential diagnosis.

Diagnosis	Preliminary diagnosis$^+$		Final diagnosis*	
	No EHR used	EHR used	No EHR used	EHR used
Aortic aneurysm	33.3% (4)	0% (0)	66.7% (8)	14.3% (2)
Pericarditis	0.0% (0)	7.1% (1)	0% (0)	0% (0)
Acute coronary syndrome	33.3% (4)	35.7% (5)	16.7% (2)	14.3% (2)
Esophageal spasm	0.0% (0)	7.1% (1)	8.3% (1)	7.1% (1)
Pulmonary embolism	8.3% (1)	0% (0)	8.3% (1)	0% (0)
Musculoskeletal chest pain	25% (3)	50% (7)	0% (0)	57.1% (8)

Note: The table entries are the percentages of cases diagnosed with and without EHR use.

Table 4
Abdominal pain scenario A – differential diagnosis.

Diagnosis	Preliminary diagnosis$^{n/a}$		Final diagnosis$^{n/a}$	
	No EHR used	EHR used	No EHR used	EHR used
Peptic disease	8.3% (1)	0% (0)	25% (3)	0% (0)
IBS	41.7% (5)	78.6% (11)	58.3% (7)	92.9% (13)
Diverticulitis	8.3% (1)	0% (0)	0% (0)	0% (0)
Epiploic Appendicitis	8.3% (1)	0% (0)	0% (0)	0% (0)
IBD (Inflammatory bowel disease)	8.3% (1)	0% (0)	0% (0)	0% (0)
Incarcerated Hernia	0% (0)	7.1% (1)	0% (0)	0% (0)
Gastroenteritis	8.3% (1)	7.1% (1)	8.3% (1)	7.1% (1)
Pancreatitis	8.3% (1)	0% (0)	8.3% (1)	0% (0)

Note: Data do not sum up to 100% due to cases in which none of the above diagnoses was made.

Table 5
Abdominal pain scenario B – differential diagnosis.

Diagnosis	Preliminary*** diagnosis		Final diagnosis**	
	No EHR used	EHR used	No EHR used	EHR used
Muscle pain	7.7% (1)	0% (0)	15.4% (2)	0% (0)
Renal vein thrombosis	0% (0)	0% (0)	7.7% (1)	0% (0)
Nephrolthiasis	15.4% (2)	7.7% (1)	38.5% (5)	23.1% (3)
Abdominal aortic aneurysms	0% (0)	84.6% (11)	0% (0)	76.9% (9)
Radiculitis	76.9% (9)	7.7% (1)	30.8% (4)	0% (0)

Note: Data do not sum up to 100% due to cases in which none of the above diagnoses was made.

Table 6
Admission decision rate.

Admission decision rate for all cases			Change rate in admission
Scenario	Access to EHR percentage (number of physicians)	No access to EHR percentage (number of physicians)	
Chest Pain – Scenario A*	92.3% (12)	58.3% (7)	+58.32%
Chest Pain – Scenario B*	71.4% (10)	100% (12)	−28.6%
Abdominal Pain – Scenario A***	0% (0)	41.7% (5)	–
Abdominal Pain – Scenario B***	100% (13)	23.1% (3)	+332.9%

Note: Because the admission rate for abdominal pain – Scenario A was zero we ran a Fisher test.

Table 7
EHR contribution to admission decisions (cases 1, 4).

Variables	Beta	S.E. (standard error)	OR (odds ratio)	95% C.I. for OR	
				Lower	Upper
EHR Used[a]	4.531	1.341	92.814	6.7	1286.41
Time (minutes)	.082	.119	1.086	.859	1.371
Specialty[b]	−1.232	.955	.292	.045	1.898
EHR familiarity[c]	−.136	.203	.873	.587	1.299
Years of EHR experience	.294	.201	1.341	.904	1.990

The correlation between the two independent variables: "EHR familiarity" and "Years of EHR experience" showed that these two variables were not associated.
[a] *Note*: Coded as: 1 = access to EHR, 0 = No access to EHR.
[b] Coded as: 1 = Internal, 0 = Emergency.
[c] Coded on a scale of 1–9 (9 representing higher levels of familiarity).

Table 8
EHR contribution to discharge decisions (cases 2, 3).

Variables	Beta	S.E.	OR	95% C.I. for OR	
				Lower	Upper
EHR Used[a,**]	−1.891	.702	.151	.038	.597
Time (minutes)	−.138	.096	.871	.722	1.050
Specialty[b]	−.814	.722	.443	.108	1.823
EHR familiarity[c]	.085	.151	1.089	.811	1.462
Years of EHR experience	−.040	.132	.961	.741	1.245

In order to assess the contribution of EHR use to admission decisions, and compare it to that of the other variables, we ran two logistic regression analyses (see Table 7 for admission decisions and Table 8 for discharge decisions). We used the Enter mode in the regressions to present the impact of each variable on the admission decisions in the results (Tables 7 and 8). We also ran the same regressions in Stepwise (not shown here), but the results showed that the only significant variable was the "EHR Used" as we discuss in the paragraph concerning use of the Enter mode.

As shown in Table 7, EHR was the only variable that significantly predicted ($p < 0.01$) a high increase in admission rates.

In addition, EHR use significantly contributed ($p < 0.01$) to predicting discharge decisions. Using EHR was associated with an 84.9% reduction in admission decisions.

6.4. Impact of using EHR on Time management and Diagnostic confidence

Using EHR led to a significant increase in the mean confidence level by 0.9 points (approximately 16%), compared to the mean confidence level without using EHR. The level of confidence in the preliminary diagnosis was unaffected by using EHR (Table 9).

In terms of time management, using EHR reduced the mean time for diagnosis and management by more than two minutes (Table 9).

Table 9
EHR impact on the diagnosis confidence.

	Mean without EHR (SD)	Mean with EHR (SD)
Time**	11.96 (3.83)	9.67 (3.04)
Confidence in preliminary Diagnosis[n/a]	(1.58) 5.39	(2.86) 5.31
Confidence in final Diagnosis*	(2.53) 5.68	(2.29) 6.59

Note: Differences were subjected to Mann–Whitney test for confidence levels, which were represented on a Likert-type scale and therefore treated using parametric statistics.

7. Discussion

Overall, the findings suggest that using EHR helps improve the quality of medical decision-making. The physicians who had access to the system took advantage of the availability of patients' medical history. EHR access appeared to valuable time and provides a more comprehensive picture. The results also supported the hypotheses, as detailed below. This may imply that physicians make more accurate decisions by using EHR which may optimize the health care given to patients.

Unlike memory-based medical history from a medical interview, the documented medical histories provided by the EHR was probably the key factor that led to more correct diagnoses. Higher rates of correct diagnosis were accompanied by a decrease in erroneous diagnoses, a crucial factor in improving quality and safety of care. In 'Chest pain scenario A', access to the EHR substantially raised the percentage of physicians who diagnosed the patients correctly. In 'Chest pain scenario B', a vital piece of information from the patient's medical history differentiating two likely diagnoses was recorded in the EHR. The results show that without the access EHR, most physicians made an inaccurate diagnosis. In both abdominal pain scenarios, EHR use increased the accuracy of diagnosis (Hypothesis 1 supported). These findings illustrate the importance of access to EHR as a source of previous medical information, which medical staff might not have in situations when no oral information is available or incomplete, when patients are unconscious, disorientated or unable to speak coherently for any reason.

The effect of EHR access on admission decisions varied with the scenario. As expected, in the case of 'Chest pain scenario A', using EHR raised admission rates and in 'Chest pain scenario B' using EHR lowered admission rates. These results suggest that physicians were in a position to make more informative admission decisions on patients because of the severity of their symptoms, in addition to previous medical history found in the EHR. In the abdominal pain scenarios, the results were comparable; in scenario A, EHR use decreased the rate of admissions and in scenario B, EHR use increased the rate of admissions. The EHR can thus enhance the physician's understanding of a patient's status and illness and enable better medical service. These results suggest that preliminary exposure to medical records puts physicians in a better position to make more informative admission decisions (Hypothesis 2 supported).

The physicians who accessed EHR were significantly more confident in their diagnoses; however, this was only true for the final diagnosis (after the test results were available) and not for the initial diagnosis (Hypothesis 3 supported for the final diagnosis). This may be due to the fact that decision-makers need specific information to be confident about their medical decisions. Given their typical work flow, physicians will wait to make a decision until all the required information (such as lab tests and imaging) has been obtained. The additional EHR information contributed to the traditional decision-making process. Thus, medical records provide important clues whose impact is stronger after test-based information, such as previous ECG, CT, blood tests, etc. have been obtained for comparative purposes.

The findings showed that the physicians who accessed EHR spent less time on each individual case (Hypothesis 4 supported). This finding could potentially lead to more efficient, cost effective, and ultimately better care in EDs. The physicians in this study were already familiarized with the system and used it in their daily routines. Physicians without access to EHR may have spent more time on each treatment because of lack of access. Previous researchers have found that EHR saves time for numerous reasons including searching for patients' charts [88], documenting symptoms, conditions and treatments [89], efficient medical data sharing between clinicians [90], etc. which led us to believe that the time saving effect of EHR derives from use of the system. EDs are overcrowded and EHR may increase physicians' efficiency by reducing the time needed for each patient. This finding may counter one typical claim that computerized information systems take time away from physicians' prime obligation to care for patients.

Overall, these results show that EHR access results in better care by providing more information, which helps reach a more correct diagnosis. Physicians are more confident in their diagnosis and take less time to draw conclusions. Thus, EHR use can contribute to health care providers and has the potential to improve medical care. Consistent with previous findings [91], an EHR system emerges as clearly beneficial to the health care sector.

8. Contributions, limitations and future research

In recent years, the use of EHR has grown worldwide as well as in Israel, where increasingly more hospitals and health care providers have recognized its benefits. However, it is difficult to pinpoint the specific factors contributing to improved care. One of the major issues in this field is whether the information provided by the EHR is effective (in terms of both better care and time) and whether it helps physicians in their decision-making. The findings here suggest that the use of EHR improves medical decision-making in terms of accuracy of diagnosis and correct admission decisions, as well as better quality of care, as shown in the reduction in the percentage of wrong diagnoses. One in every seven admissions to an ED can be attributed to missing information [92]. This study provides evidence that EHR use in the ED affects the process of medical decision-making by enabling more accurate diagnoses. This study contributes to medical decision-making policy in the sense that the results show how access to an EHR can improve patient care and savings in time and money. The findings may help increase the cooperation and willingness of medical staff to adopt an IT system by demonstrating its contribution to correct diagnoses.

Our study also has limitations. First, the finding were only obtained on two cases (chest pains and abdominal pain) in four scenarios and with a specific EHR (OFEK). This may limit the generalizability of the findings. Second, the study took place in a simulated environment that did not fully resemble the authentic conditions of a real, busy ED where multiple patients and staff crowd the physicians and create considerable distraction. The simulation environment did, however, enforce time constraints and a beehive surrounding. To contribute to the realism, we did not maintain a quiet, sterile environment in the simulation rooms, but generated the hustle and bustle with four physicians working in parallel and a few members of the research team all packed into a small space. In addition, the participants work in an ED which already has a fully functional EHR system. This could help explain the lack of confidence and greater time spent on diagnoses in the participants who did not have access to the system. Third, the participating physicians volunteered to take part in the simulation study and differed in terms of their seniority, their prior experience with these specific cases (or ones like them), their specialty, their experience with the EHR and other factors. This, might have biased the results of the study and the accuracy of the diagnoses. However, we conducted several statistical analyses including logistic regressions, which reduced the likelihood of this bias.

In addition, some of the physical findings (such as elevated heart rate and high blood pressure) were impossible to replicate as is, since the actors were healthy. However, physicians were aware of the simulation situation and could ask questions or examine the patient and obtain information verbally or in written form. The SPs were credible patients since they were highly experienced in simulating patients in training and examination projects. Second, for standardization reasons it was important to use actors (most real patients would have been unable to describe the same symptoms over and over again). Finally, patient safety reasons precluded using real patients (recruiting patients with acute abdominal pain would have been unethical). Future projects could use mannequins or robot simulating symptoms and other variables (such as heart rate) to avoid such difficulties. All the physicians who took part in the simulations were in the middle of their work day, and all were eager to complete their cases and get back to their wards. Future research could also take more clinical cases into consideration, as well as other EHR systems (which may vary in their user-friendliness in terms of real-time accessibility to patient data) and in terms of the actual environment (i.e., conducting the study in a real ED). In addition, the EHR (OFEK) is developing its capabilities to work on mobile devices at all points of care, including the ED. Thus, it would be worthwhile to study the impact of such incremental technology in the crowded ED environment.

HIT designers, medical staff, patients and policy makers can benefit from the data shown here. EHR assimilation can improve the care given to patients and enhance the efficiency and safety of the system. There is a growing need for training medical staff and exposing them to HIT and its benefits. The findings also suggest investing in a system that will allow sharing of information between health care providers to increase the pool of information provided to medical staff at the point of care.

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Appendix A. "OFEK" system (EHR system)

The "OFEK" system was developed by dbMotion. This system enables health care organizations to share medical information. OFEK connects health care providers, which ensures the system's interoperability within the organization itself and with other organizations. Access to the system's information is given to authorized users online.

OFEK collects medical information from the participating systems (distributed health care providers, external labs, pharmacies, hospitals, medical institutes and community clinics). Then, the information is integrated into a Virtual Patient Object (VPO) representation of the patient and his or her relevant information in the system. via the VPO, OFEK can analyze the VPO to search for more information by identifying the patient (OFEK has its own search engine). The information sources include prior hospitalizations, prior diagnoses, medication lists, allergies, previous lab results, primary physician medical records, etc. (see Fig. 1).

Appendix B. Research and medical rationale for the scenarios

B.1. Chest pain – Scenario A

This scenario was initially designed as one in which physicians with and without access to information from OFEK would decide to admit the patient. The information in this scenario included a

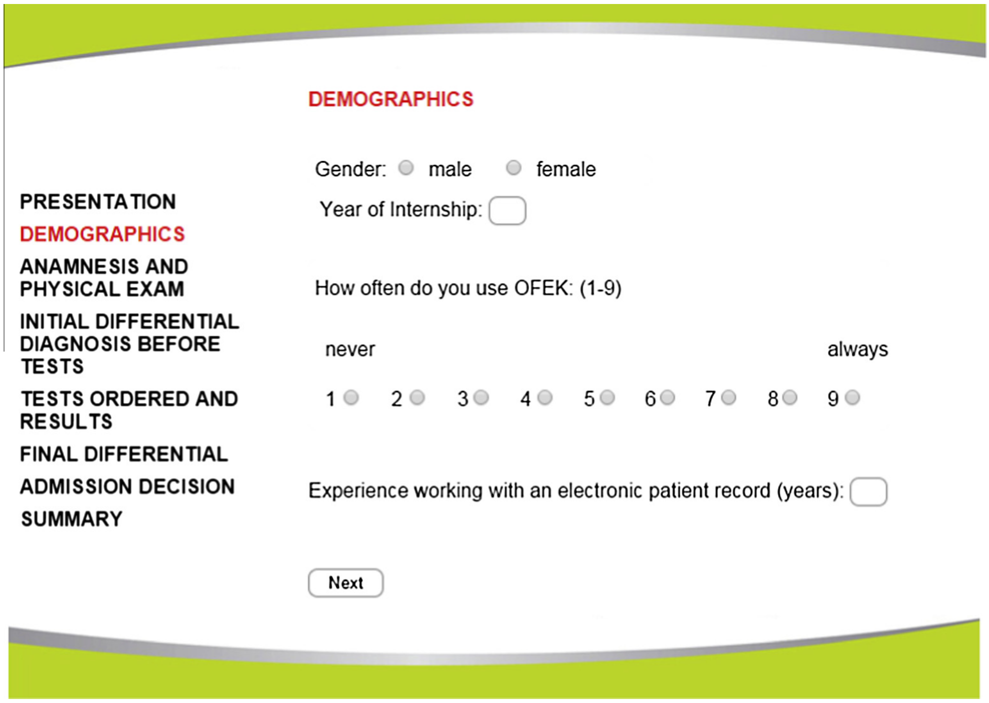

Fig. 1. The demographics questionnaire screen in the simulation study (the first screen).

clinical history of skeletal muscle pain and auxiliary data (previous ECG for OFEK users and current ECG for all physicians) designed to arouse suspicion and the need to rule out an acute coronary event. In this case physicians were expected to admit the patient (with or without access to OFEK). The physicians found the information inconclusive. Physicians with no access to OFEK were unsure whether to admit whereas the overwhelming majority of physicians who had access to OFEK decided on admission.

B.2. Chest pain – Scenario B

This scenario was designed to elicit a severe diagnosis of dissection of aortic aneurysm and admission with no access to OFEK, and a diagnosis of skeletal muscle pain and discharge with access to OFEK. The information obtained from the patient indicated skeletal pain with a description of pain that made it imperative to rule out a coronary event. If the physician decided to order an ECG, it came back normal. By contrast, the chest X-ray showed an expansion of the marker (which may suggest an aortic aneurysm) which requires additional and urgent testing. Physicians who had access to information via OFEK saw a discharge letter from the hospital that had examined the expansion of the marker, and rejected the diagnosis of aortic dissection. In this scenario, the physician who only had access to the hospital information alone was expected to admit the patient and order urgent tests. Physicians with access to OFEK could associate the chest pain to the skeletal muscle pain and discharge the patient (with or without further tests in the community).

B.3. Abdominal pain – Scenario A

In this scenario, the patient has severe abdominal pain (cannot stay still). OFEK contains information regarding a gastro procedure performed at another hospital. This investigation did not find any clinical symptoms and concluded that the patient suffers from irritable bowel syndrome (IBS). Physicians with no access to OFEK were expected to send the patient to undergo the same set of tests to diagnose the source of pain and admit the patient. Physicians with access to OFEK were not expected to send the patient to repeat these tests. In the experiment, physicians with no access to OFEK were expected to admit the patient for further tests, and discharge the patient.

B.4. Abdominal pain – Scenario B

In this scenario the information provided by the patient could suggest a spine problem or nephrolithiasis. The information provided by OFEK indicated a life-threatening condition where the physician must take immediate action. The patient reports hip pain and pain radiating to the left leg. Blood tests suggest Nephrolithiasis, although the US disconfirms this. Back and spine imaging are normal. Without access to OFEK physicians are likely to suspect kidney stones or back problems. OFEK contained a CT scan with a new life-threatening finding of an abdominal aortal aneurysm. In this scenario OFEK reveals a life-threatening condition, and enables the patient to avoid a CT exam with injected contrast materials. Although we did not plan this, hip pain and pain radiating to the left leg led many physicians to suspect radiculitis problems. In the experiment without access to OFEK physician were expected to discharge the patient. However, physicians with access to OFEK were expected to admit the patient.

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