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The Effect of Electronic Systems on Minimizing Errors in Family Medicine Clinics

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Abstract

Objectives: *To assess the efficacy of implementing an electronic health record (EHR) system in reducing the rates of medical errors (MEs) in a Saudi outpatient clinic.*

Methods: *A descriptive, cross-sectional study was conducted over one month on two phases: phase I (pre-EHR) and phase II (post-EHR) in 2009 and 2019, respectively. In both phases, all healthcare providers (HCPs) and employees working at the Family medicine clinic, the pharmacy and the laboratory at King Abdul Aziz Residential City Center, Riyadh, Saud Arabia, were invited to report the experienced errors during their daily work activities. A specifically-designed error note sheet was used to collect MEs allocated to 10 main categories.*

Results: *Prescription errors (69.3%), medication errors (13.4%) and documentation errors (6.6%) were the most frequent MEs in phase I, while communication errors, documentation errors and medication errors (38.2%, 18.7%, and 14.7%, respectively) were prevalent in phase II. As compared to manual recording, EHR system implementation reduced prescription errors (from 69.8% to 3.0%, p<0.001), medication errors (13.5% to 3.2%, p<0.001), and professionalism errors (1.9% to 0.3%, p<0.001), and completely eliminated case note missing (p<0.001) and clerical errors (p<0.001). However, communication errors increased significantly after EHR use as compared to the pre-EHR period (from 0.5% to 8.3%, p<0.001).*

Conclusion: *Although the majority of MEs significantly reduced with EHR implementation, some technical and/or usability barriers to its use among HCPs should be addressed. The efficacy of relevant training programs and statistical models aimed at reducing the rates of increased/unaffected MEs are to be investigated in future Saudi-based studies.*

Background

Error is an inevitable fact of life. It entails all aspects of daily activities, in every population, and in every occupation with varying rates and a broad spectrum of consequences. Generally, an error is defined as an instance in which a sequence of physical and mental activities fail to meet and achieve the prospected outcomes, while such failures cannot be ascribed to the intervention of chance agency[1].

In essence, medical errors can lead to preventable adverse events in healthcare settings. This is true whether or not the error is evident or resulted in harmful consequences to the patient [2]. However, little is known about the relationship between errors and adverse events. Besides, according to the World Health Organization, mortality statistics in 117 countries are coded using the ICD system (ICD-11), which has some limitations in the coding of adverse events related to medical errors,

such asthe code for overdose adverse event and the code of events attributable to anticoagulation [3].

Therefore, getting deeper insights into the burden of medical errors is imperative. Adverse events occurred in 3.7% of hospitalized patients in an early cross-sectional study in the United States [4]. Similar figures were reported in other countries, such as 2% of admitted patients in New Zealand [5], 0.66% in France [6], and 0.4% in Australia [7]. However, higher rates were reported in Iran (7.3%)[8] and Ireland (10.3%) [9]. Additionally, a recent systematic review of 74,485 patient records showed a pooled incidence of in-hospital adverse events of 9.2% [10].

In Saudi Arabia, the actual burden of medical errors is poorly investigated. Concomitantly, the frequency of medical error claims is increasing and this can partially reveal their domestic incidence. Early and recent studies showed a significantly increasing trend of filed medical claims as revealed from the records of Medico-legal Committees (MLCs)[11-14]. However, medical errors are still underreported by physicians due to either the lack of knowledge about their significance, particularly for non harmful errors, or due to the fear of punitive actions[13]. Therefore, there is an urgent need to address medical errors to reduce such substantial burden concerned with patient safety and physician-related issues.

Electronic medical records (EMRs) comprise a strategy which aims at reducing these errors. It was developed not only to digitally reproduce the paper charts, but also to interact with humans to create a complex system of care. Therefore, since its introduction in the United States, the EMR system has revolutionary transformed the medical practice from a paper-based system into an integrated and a comprehensive healthcare system[15]. By 2010, more than 50% of American healthcare systems had incorporated EMRs into their practices[22].

At the same time, e-health services were increasingly growing in Saudi Arabia. The Ministry of Health (MOH) had allocated SAR 4 billion to run a national e-health program during the period between 2008 and 2011[16]. In addition, a number of conferences have been held to corroborate the importance of e-health systems in enhancing the quality of care and reducing the rates of medical errors. Accordingly, the Saudi Association for Health Information started to set appropriate plans, strategies, and policies as well as to employ suitable infrastructure for such systems[17]. However, some unintended consequences have emerged due to EMR utilization, such as communication issues, complexity of care processes, and alert fatigue. Therefore, these challenges should be addressed to optimize patient care and improve health systems……

Methodology
Study Design
A descriptive, observational, cross-sectional study was conducted, considering qualitative data as self-reported by the participants. The study comprised a comparison between two separate phases with a ten-year interval in-between. A pre-EMR implementation phase (Phase I) and post-implementation phase(Phase II) were conducted in 2009 and 2019, respectively.

Study Population
The participants included all healthcare providers and employees working at the study setting. These included physicians, pharmacists, nurses, technicians (radiology and laboratory), and unit assistants. All participants with different levels of working experience were eligible.

In both phases, the researchers interviewed the participants in each department, explaining the rationale and objectives of the study. Furthermore, any queries were addressed in detail.

Study Setting
The study was conducted at the Family medicine clinic located at King Abdul Aziz Residential City Center (Iskan Yarmouk) in Riyadh, Saud Arabia.

The family medicine clinic is operated under an EMR system for patients' booking, referral, investigations, and medication dispensing at the pharmacy. The EMR system (BESTCare®) was first implemented at the Ministry of National Guard Health Affairs (MNGHA, Riyadh) in January 2016.BESTCare®comprises of three main domains, including the core applications, channel domains, and information infrastructure and multiple critical applications, such as EMR, CPOE, CDS, close-loop medication administration, health information exchange, etc.[53].The system can be easily customized and fully integrated and it has been adapted into three languages, including English, Chinese and Arabic.

Several functionality domains of such a system have been tested and successfully validated in Saudi hospitals, including supportive care and documentation integrity[54, 55].

Definitions

A medical error was defined according to Reason[18] as any event failed to be completed as intended or utilizing a wrong plan that failed to achieve the proposed target. A comprehensive taxonomy of errors was built by the researchers to facilitate the processes of categorization and coding for subsequent analysis. The used taxonomy is demonstrated in detail in Table 1.

Table 1: Classification of errors encountered in the current study

Error Class	Sub class
Prescription errors	• no diagnosis
	• no allergy
	• no weight or height.
	• no physician names.
	• no physician badges.
	• no physician signatures.
	• no date.
	• no time.
	• incompatible visit and dispense date.
Medication Errors	• incorrect Medication.
	• incorrect spelling.
	• incorrect duration.
	• incorrect dose.
	• incorrect combination
	• unclear medication.
	• incomplete medications.
	• no or unclear status
Documentation Errors	• incomplete progress note.
	• incomplete lab request.
	• incomplete pathology request.
	• incomplete radiology request.
	• incorrect lab request.
	• incorrect pathology request.
	• incorrect radiology request.
	• incomplete medical report.
	• incorrect medical report.
	• incorrect medical report form.

	•	incorrect documentation site.
Case Note Missing Errors	•	File
	•	progress note.
	•	lab request.
	•	prescription
Appointments Errors	•	incomplete appointment slip.
	•	overbooking.
	•	unscheduled booking
	•	incorrect SMS
Communication Errors	•	No answer from other department.
	•	incorrect referral path.
	•	File was received late.
Clerical Errors	•	incorrect patient papers
	•	incorrect form.
	•	incomplete papers.
	•	papers of another patient.
	•	incorrect file.
	•	incorrect MRN
	•	no stamp
	•	no label
Patients Errors	•	Patientwas not cooperative.
	•	Patient did not show up.
	•	Patient's relative came to refill medication.
	•	Patient asked procedure without request
Equipment, Facilities and logistic Errors	•	Computer ran slowly.
	•	computer was not working.
	•	supply shortage e.g. gloves.
	•	insufficient supply to patiente.g. urine, stool containers.
Professionalism Errors	•	doctor came late.
	•	doctor left early.
	•	Unit assistant came late.
	•	doctor didn't bring his/her own instruments e.g. stethoscope, pen etc.

Sampling technique and sample size calculation

No sampling technique or sample size calculation methods were used in this study since all participants working in study settings were allowed and invited to report the encountered errors.

Data collection tool (instrument)

A specific "error note sheet" was developed for the purpose of the study in Arabic and English languages to facilitate reading and reporting (**Error! Reference source not found.**Figure 1). Each participant had to fill in spaces regarding the date of incidence of the error, medical record number, and a brief description of the error. A reminding note entailing the definition of error was placed at the top of each sheet.

Data collection technique

Phase I started in February 1st 2009 while Phase II started on February 1st 2019. Data collection for both phases lasted for four weeks. In phase I, the participants reported their experienced errors with

conventional (handwritten) record systems in the error note sheet. The same applies for the participants who used the EMR system in phase II.

The participants were encouraged to report the errors in Arabic or English whether or not they caused harm to the patient and whether or not they induced unintended consequences to the care process. The sheets were attached to a locked box with a top hole. Several boxes were distributed in all clinical areas involved in the study. Following providing a clear and brief description of the error, the participants were instructed to place the error note sheet inside the box. Additionally, a reminding poster was placed in each clinical area to continually maintain the participants' alertness regarding the study objectives. At the end of each phase, all boxes were opened, the sheets were collected and the errors were classified as previously mentioned (Table 1).

Statistical analysis

The Statistical Package for Social Sciences version 21.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Categorical data, including error types after using handwritten or EMR reporting systems, were presented as frequencies and percentages. The average rate of error per patient was computed the total number of errors when either manual or EMR systems / total number of patients who were booked in the clinic during the study period;

which includes patients who were affected or presumably affected by the error. The impact of the electronic recording system on error types was analyzed by comparing the percentages of each type in electronic versus manual system using Chi-squared test; these percentages were calculated using the following formula: the frequency of error (by type) / total number of patients booked at that day. Statistical significance was deemed at a P value < 0.05.

Results
Frequency of errors
We identified 455 medical errors in the clinic among total 2103 patients booked during the period of February 2019, which accounts for an average 0.22 error by patient. By comparison, manual method (pre-system period, February 2009) entailed 866 errors among total 860 patients, accounting for an average 1.01 error by patient.

Comparison of Error Types in Electronic versus Manual Method
Communication error was the most frequent type of errors accounting for 38.2% of the errors in electronic method; followed by documentation error (18.7%) and medication errors (14.7%). By contrast, the three most frequent error types in manual method (2009) were prescription errors (69.3%), medication errors (13.4%) and documentation errors (6.6%) (Table 2).

Table 2: Error type in electronic versus manual method

Error type	Method (date)			
	Manual (2009)		**Electronic (2019)**	
	Freq.	**%**	**Freq.**	**%**
Prescription Errors	600	69.3	63	13.9
Medication Errors	116	13.4	67	14.7
Documentation Errors	57	6.6	85	18.7
Case Note Missing	12	1.4	0	0.0
Appointment Errors	5	0.6	16	3.5
Communication Errors	4	0.5	174	38.2
Clerical Errors	30	3.5	0	0.0
Patient Errors	4	0.5	21	4.6
Equipment's & Facilities Errors	22	2.5	23	5.1
Professionalism Errors	16	1.8	6	1.3
Total	**866**	**100.0**	**455**	**100.0**

Percentage is calculated on the total number of errors.

Effect of Implementing Electronic Method on Error Incidence by Error Type

The implementation of the electronic system reduced significantly majority of errors, notably prescription errors (from 69.8% to 3.0%, p<0.001), medication errors (13.5% to 3.2%, p<0.001), and professionalism errors (1.9% to 0.3%, p<0.001). Further, the implementation of the electronic system suppressed both case note missing (p<0.001) and clerical errors (p<0.001). No significant impact was observed regarding appointment errors (p=0.810) and patient-related errors (p=0.187). On the other hand, we observed an increase in the incidence of communication errors from 0.5% to 8.3% (p<0.001) (Table 3).

Table 3: Impact of electronic method by error type

Error type	Method (date)				
	Manual (2009)		Electronic (2019)		p-value
	Freq.	%	Freq.	%	
Prescription Errors	600	69.8	63	3.0	<.001*
Medication Errors	116	13.5	67	3.2	<.001*
Documentation Errors	57	6.6	85	4.0	.003*
Case Note Missing	12	1.4	0	0.0	<.001*
Appointment Errors	5	0.6	16	0.8	.810
Communication Errors	4	0.5	174	8.3	<.001*F
Clerical Errors	30	3.5	0	0.0	<.001*
Patient Errors	4	0.5	21	1.0	.187F
Equipment's & Facilities Errors	22	2.6	23	1.1	.003*
Professionalism Errors	16	1.9	6	0.3	<.001*

Percentage is calculated on the total number of patients booked. Test used chi-square test; * statistically significant (p<0.05).
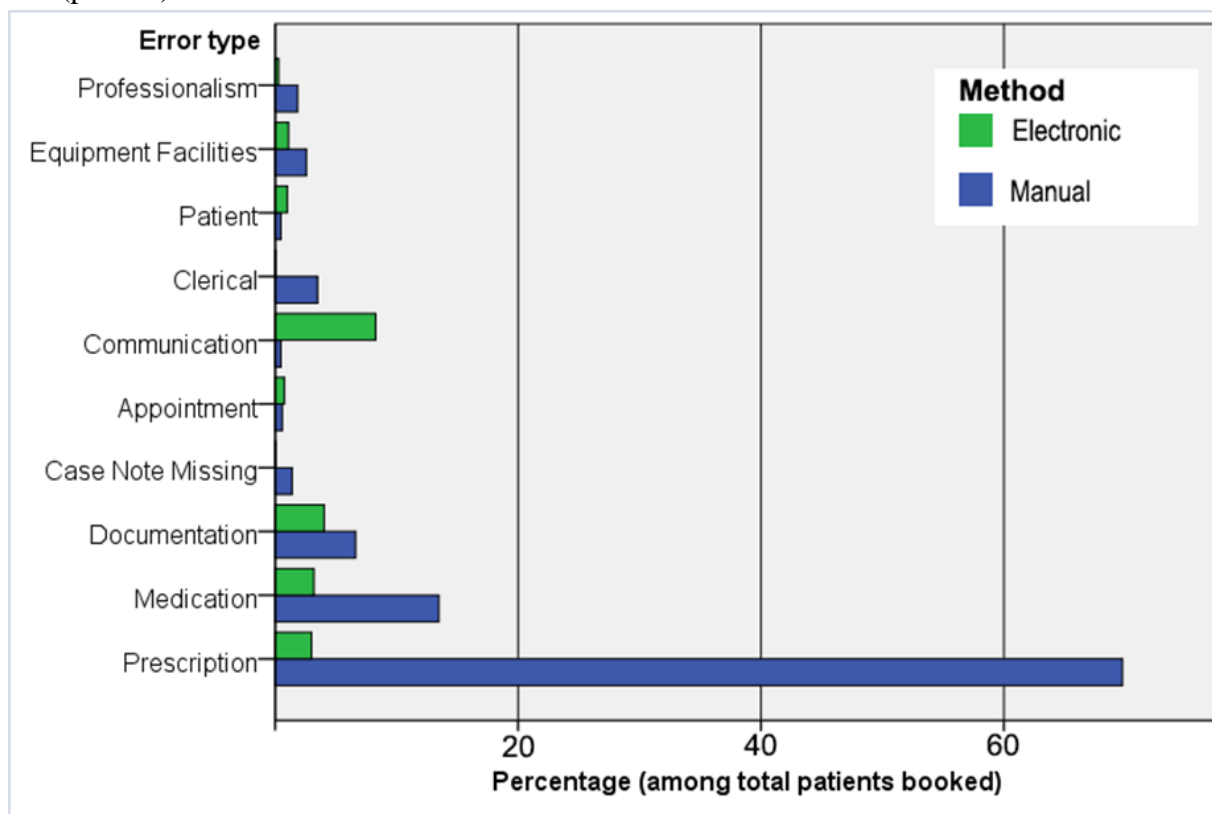

Figure 1: Impact of electronic method by error type.

Discussion

Our results regarding all types of errors showed a 4.5-fold reduction in the probability of occurrence of any error by patient. Similar results were demonstrated in the literature. Similarly, in a descriptive qualitative study comprising of family medicine specialists in Al Ain, United Arab Emirates, the role of EMR system in reducing medical errors and prescribing errors was emphasized by the majority of participants [19]. The advantages of electronic systems have also been highlighted by 2719 American family medicine physicians, since it was easy to use, precise, fast and reduced the rates of errors[20]. Interestingly, nurses have emphasized the significance of EMR on inducing fewer errors, facilitating reporting and access to information and increased the frequency of complete records [21].

The impact on Prescribing and Medication Errors

The effects of EMR systems on prescription and medication errors was significant in our study. Likewise, several studies have reported substantial reductions in the frequencies of medication and prescribing errors after using EMR systems [22, 23]. Singer and Duarte Fernandez[24] showed that EMR implementation was associated with a significant reduction of the number of incorrect dose notifications, clarification requests, and interaction notifications between family medicine prescribers and pharmacists.

In emergency pediatric departments, which have the highest rates of preventable adverse events and medication errors in hospitals [25], EMR systems led to a significant reduction of antibiotic prescribing errors and dosing errors [26].

The variation in error rate reduction could be explained by discrepancies in the used systems and differences in system usability. It seems that there are variable degrees of computer skills and technical support that contributed to differences in EMR adoption, implementation, and development [27].

The Unaffected Domains

We showed no significant effects of EHR systems on appointment and patient-related errors. Indeed, there was a non-significant trend of increased frequency of appointment errors with EHR use. This finding appears to be paradoxical given that appointment management is an essential property of electronic systems. On the other hand, where appointment errors may be difficultly detectable and trackable using the manual method, the implementation of the EHR have probably unveiled such errors; which explains the apparent increase in their incidence. Indeed, researchers used electronic records to support advanced predictive models to improve appointment and booking errors. For example, Huang and Hanauer[83] developed an EHR-dependent evidence-based system to address patient no-shows, which occur when a patient does not arrive for a previously booked appointment. These incidents would increase healthcare costs, decrease clinic efficiency, cause resource underutilization, and reduce provider productivity. Based on data related to patient's demographic characteristics and scheduling systems, the developed approach resulted in a significant reduction of overtime (by 24%-29%) and average wait time (6%-8%)[83]. Similarly, Mohammadi et al.[84] used several variables from EHR data, including the time difference between the day of the visit and the actual contact day for booking, previous no-show rate, and other demographic data, and successfully developed a machine learning model to predict no-show behavior.

Therefore, rather than direct appointment error detection, EHR systems can be customized and utilized to develop further algorithms to reduce no-show rates and organize booking systems. Additionally, the same principles could be applied to predict other patient-related errors, such as asking procedures without requests and the lack of cooperation, based on previous incidents.

However, as revealed in our study, the efficiency of computer-based algorithms remains limited to differentiate these errors since they are pertinent to human factors, which are not under the full control of the system.

Communication Errors

The impact of EHR was evident on promoting faxed communications between family medicine physicians and pharmacists [24]. Garvey and Evensen[28] have pointed out that a specific computer-based tracking system embedded in the EHR improved communication between physicians and patients with cervical cytology abnormalities during their follow-up periods.

Contrastingly, defects in the interdisciplinary communications have been reported. For example, interactive communication between physicians was the lowest perceived benefit of EMR systems among pediatricians working at King Saud University Medical City[29].Receiving no answer from other departments, delayed referral request response, and incorrect referral path constituted all communication errors encountered in our analysis. Such a delay would affect the process of care and threaten patient's safety.

Limitations

In the present study, we experienced several limitations. The most impactful limitation is the lack of a consistent definition for error types to be clearly presented and interpreted by EHR systems. Variations in the perception of different error types would affect the patterns of reporting and hence the outcomes may be biased. Additionally, we could not assess the impact of electronic systems on the incidence of medical errors during the first years of implementation. Comparing user's perceptions and system usability between the initial current periods would provide deep insights into the defective aspects and the barriers experienced by the users. Furthermore, detailed descriptions regarding the frequency of error subtypes (i.e. errors within the medication error domain) were not provided and thus could not be analyzed and interpreted.

Conclusion

The implementation of innovative technologies in the healthcare sector is growing in Saudi Arabia to address the burden of apparent medical errors. We showed that the overall error rate per patient significantly reduced from 1.01 to 0.22 with effective implementation of a promising EHR system as compared to the traditional handwritten record system. Prescription and medication errors were frequently reported and were significantly higher using the manual method, than the digitized system, indicating enhanced patient safety with using the latter system. Further, EHR use improved detection of inter-professional communication errors, thereby enabling the planning of corrective actions and improvement of eventual technical barriers.

Recommendations

Future studies concerning barriers to EHR use in Saudi hospitals are warranted. Integrative models to predict appointment errors should be investigated and developed to promote system capabilities to detect this type of errors. Conducting large scale studies which compare the impact of different types of commercial EHR systems would be beneficial to enhance their usability. To address communication problems, EHR users should be adequately trained to improve their communication skills and such training should be incorporated into all stages of medical training. System developers are required to make the systems easier to use and more user-friendly, considering the technical barriers.

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List of Abbreviations

Abbreviation	Description
CDS	Clinical Decision Support
CPOE	Computerized Physician Order Entry
EHR	Electronic Health Record
EMRs	Electronic Medical Records
IOM	Institute of Medicine
KSA	Kingdom of Saudi Arabia
MLCs	Medico-Legal Committees
MOH	Ministry of Health
SCHS	Saudi Commission for Health Specialties
SDFM	Saudi Diploma in Family Medicine