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Defining Health Information Technology-related Errors: New Developments Since *To Err is Human**

Dean F. Sittig, PhD¹ and Hardeep Singh, MD, MPH²

¹University of Texas – Memorial Hermann Center for Healthcare Quality & Safety, National Center for Cognitive Informatics and Decision Making, School of Biomedical Informatics, University of Texas Health Sciences Center, Houston, TX

²Houston VA Health Services Research and Development Center of Excellence and The Center of Inquiry to Improve Outpatient Safety Through Effective Electronic Communication, Michael E. DeBakey Veterans Affairs Medical Center and Section of Health Services Research, Department of Medicine, Baylor College of Medicine, Houston, TX

Summary

Despite its promise, recent literature has revealed possible safety hazards of health information technology (HIT) use. The Office of the National Coordinator for HIT recently sponsored an Institute of Medicine committee to synthesize evidence and experience from the field on how HIT affects patient safety. To lay the groundwork for defining, measuring, and analyzing HIT-related safety hazards, we propose that Health information technology-related error occurs anytime HIT is unavailable for use, malfunctions during use, is used incorrectly by someone, or when HIT interacts with another system component incorrectly, resulting in data being lost or incorrectly entered, displayed, or transmitted. These errors, or the decisions that result from them, significantly increase the risk of adverse events and patient harm. In this paper, we describe how a socio-technical approach can be used to understand the complex origins of HIT errors, which may have roots in rapidly evolving technological, professional, organizational, and policy initiatives.

Keywords

Electronic Health Records; Health Information Technology; Patient Safety; Errors

Introduction

Two Institute of Medicine (IOM) reports have recommended the use of information technologies to improve patient safety and reduce errors in health care^{1,2}. Broadly speaking, health information technology (HIT) is the overarching term applied to various information and communication technologies used to collect, transmit, display, or store patient data. Despite HIT's promise in improving safety, recent literature has revealed potential safety hazards associated with its use, often referred to as e-iatrogenesis.^{3,4} For example, Koppel et al⁵ describe 22 types of errors facilitated by a commercially available electronic health

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Address for Correspondence: Dean F. Sittig, Ph.D. UT - Memorial Hermann Center for Healthcare Quality & Safety, University of Texas School of Biomedical Informatics at Houston, 6410 Fannin St. UTPB 1100.43, Houston, TX 77030, Work: 713-500-7977, Fax: 713-500-0766, dean.f.sittig@uth.tmc.edu.

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record (EHR) system's computerized provider order entry (CPOE) application. In response to similar emerging concerns, the Office of the National Coordinator for HIT recently sponsored an IOM committee to "review the available evidence and the experience from the field" on how HIT use affects patient safety. Given the national impact of HIT, this initiative is a major step forward in ensuring the safety and well-being of our patients. However, the field currently lacks acceptable definitions of HIT-related errors and it is unclear how best to measure or analyze "HIT errors".

The goal of this manuscript is to advance the understanding of HIT-related errors and explain how adverse events, near misses, and patient harm can result from problems with HIT itself or from interactions between HIT, its users, and the work system. Health information technology errors almost always jeopardize patient outcomes and have high potential for harm⁶ because they are often latent errors that occur at the "blunt end" of the healthcare system,⁷ potentially affecting large numbers of patients if not corrected. Furthermore, if important structural or process-related HIT problems are not addressed proactively, the care of millions of patients may be affected owing to the impending widespread adoption and implementation of EHRs⁸. We thus focus heavily on errors related to the use of EHR systems.

General Criteria for a HIT Error

We define the HIT work system as the combination of the hardware and software required to implement the HIT, as well as the social environment in which it is implemented. We thus propose that HIT errors should be defined from the socio-technical viewpoint of end users (including patients, when applicable) rather than from the purely technical viewpoint of manufacturers, developers, vendors, and personnel responsible for implementation. Health information technology related error occurs anytime the HIT system is unavailable for use, malfunctions during use, is used incorrectly, or when HIT interacts with another system component incorrectly resulting in data being lost or incorrectly entered, displayed, or transmitted.^{9,10} Errors with HIT may involve failures of either structures or processes and can occur in the design and development, implementation and use, or evaluation and optimization phases of the HIT life cycle.¹¹ This approach is consistent with the currently recommended systems and human factors approaches used to understand and reduce error.¹

The HIT system is considered to be *unavailable* for use if for any reason the user cannot enter, review, transmit, or print data (e.g., patient's medication allergies or most recent laboratory test results). Reasons could include unavailable computer hardware (e.g., missing keyboard or problems with the computer's monitor, network routers that connect the computer to the data servers and printers, or the server where data is stored), unavailable software (e.g., missing components with the operating system that manages either the computer applications such as the internet browser and EHR or the interface between an EHR system and the information system of an ancillary service such as radiology or lab), and power sources (e.g., a power outage that results in hospital-wide computer failure).⁴

The HIT system is considered to be *malfunctioning* (i.e., available, but not working correctly) whenever a user cannot accomplish the desired task despite using the HIT system as designed. In this situation, error results from any hardware or software defect (or bug) that prohibits a user from entering or reviewing data, or any defect that causes the data to be entered, displayed, transmitted, or stored incorrectly. For example, the clinician might enter a patient's weight in pounds, and the weight-based dosing algorithm might fail to convert it to kilograms before calculating the appropriate dose, resulting in a 2-fold overdose.

Finally, errors can occur even when hardware and software are functioning as designed. For instance, errors may result when users do not use the hardware or software as intended. For

example, users might enter free-text comments (e.g., “take 7.5 mg Mon-Fri only”) that contradict information contained in the structured section of the medication order (e.g., “Warfarin tabs 10mg QD”).¹² Errors may also arise when 2 or more parts of the HIT system (e.g., CPOE application and the pharmacy’s medication dispensing system) interact in an unpredicted manner, resulting in inaccurate, incomplete, or lost data during entry, display, transmission, or storage.¹³

Origin-Specific Typology for a HIT Error

Leveson¹⁴ proposes that new technologies have fundamentally altered the nature of errors and asserts that these changes necessitate new models and methods for investigating technology-related errors. Thus, technological advances could potentially give rise to increasingly complex and multifaceted errors in healthcare. In view of the resultant expanding and evolving context of safe HIT implementation and use, we illustrate how a recently developed socio-technical model for HIT evaluation and use can provide an origin-specific typology for HIT errors.¹⁵ The model’s 8 dimensions (Table 1) comprehensively account for the technology; its users and their respective workflow processes and how these 2 elements interface with the technology; the work system context including organizational and policy factors that affect HIT; and notably, the interactions between all of these factors.¹⁶ The Table lists examples of specific EHR-related errors that can occur within each of the 8 dimensions of the socio-technical model, along with examples of potential ways that the likelihood of each error could be reduced. Thus, the model not only illustrates the complex relationships between active and latent errors but also lays a foundation for error analysis.

Conclusion

In conclusion, rapid advances in HIT development, implementation, and regulation have complicated the landscape of HIT-related safety issues. Erroneous or missing data and the decisions based on them, increase the risk of an adverse event and unnecessary costs. Because these errors can and frequently do occur after implementation, simply increasing oversight of HIT vendors’ development processes will not address all HIT-related errors. Comprehensive efforts to reduce HIT errors must start with clear definitions and an origin-focused understanding of HIT errors that addresses important socio-technical aspects of HIT use and implementation. To this end, we provide herein a much needed foundation for coordinating safety initiatives of HIT designers, developers, implementers, users, and policy makers, who must continue to work together to achieve a high-reliability HIT work system for safe patient care.

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Table 1

Examples of the types of errors that can occur within each dimension of the socio-technical model¹⁶ and corresponding suggested mitigating procedures.

Socio-technical model dimension	Examples of types of errors that could occur in each dimension	Examples of potential ways to reduce likelihood of these errors...
Hardware and Software - required to run the healthcare applications	Computer or network is not functioning ¹⁷	Provide redundant hardware for all essential patient care activities
	Input data truncated (ie, buffer overflow) – some entered data lost	Warn users when data entered exceeds amount that can be stored
Clinical Content – data, information, and knowledge entered, displayed, or transmitted	Allowable item can't be ordered (eg., no "amoxicillin" in the antibiotic pick-list) ⁵	Conduct extensive pre-release testing on all system-system data and human-computer interfaces to insure that new features are working as planned and that existing features are working as before
	Incorrect default dose for given medication ⁵	
Human Computer Interface - aspects of the system that users can see, touch, or hear	Data entry/review screen does not show the patient name, medical record number, birthdate, etc.	Encourage and provide methods for clinicians to report when patient-specific screens do not contain key patient demographics so that the software can be fixed
Human Computer Interface (cont.)	Two patients with same name; data entered on wrong patient ¹⁸	Alert providers to potential duplicate patients and require re-confirmation of patient ID before saving data (eg, display patient photo before signing)
	Two buttons with same label, but different functionality	Pre-release inspection of all screens for duplicate button names
People - the humans involved in the design, development, implementation, and use of HIT	Wrong decision about KCI administration based on poor data presentation on the computer screen ¹⁹	Improve data displays and train users to routinely review and cross-validate all data values for appropriateness before making critical decisions.
	Incorrect merge of two patient's data ²⁰	Develop tools to compare key demographic data and calculate a probability estimate of similarity
	RNs scan duplicate patient barcode taped to their clipboard rather than barcode on patient to save time ²¹	Improve user training, user interfaces, work processes, and organizational policies to reduce need for workarounds
Workflow and Communication - the steps needed to ensure that each patient receives the care they need at the time they need it	Computer discontinues a medication order without notifying a human	Implement fail-safe communication (eg, re-send message to another hospital designee if no response from MD or RN) for all computer-generated actions ²² .
	Critical abnormal test result alerts not followed up ²³	Implement robust quality assurance systems to monitor critical follow-alert up rates ²⁴ ; use "dual notification" for alerts judiciously ²⁵
Organizational Policies and Procedures - internal culture, structures, policies, and procedures that affect all aspects of HIT management and healthcare	Policy contradicts physical reality (eg, required Barcode med administration readers not available in all patient locations) ²¹	Conduct pre- and post-implementation inspections, interviews, and monitor feedback from users in all physical locations
	Policy contradicts personnel capability (eg, 1 pharmacist to verify all orders entered via CPOE in large hospital)	Conduct pre- and post-implementation interviews with all affected users to better gauge workload
	Incorrect policy allows "hard-stops" on clinical alerts causing delays in needed therapy ²⁶	Disallow "hard-stops" on alerts; users should be able to override the computer in all but the most egregious cases (eg, ordering promethazine as IV push by peripheral vein ²⁷)

Socio-technical model dimension	Examples of types of errors that could occur in each dimension	Examples of potential ways to reduce likelihood of these errors...
External Rules, Regulations, and Pressures - external forces that facilitate or place constraints on the design, development, implementation, use, and evaluation of HIT in the clinical setting	Billing requirements lead to inaccurate documentation in EHR (eg, inappropriate copy & paste)	Highlight all "pasted" material and include reference to source of material
	Joint Commission required medication reconciliation processes ²⁸ causing rushed development of new medication reconciliation applications that were difficult to use and caused errors ²⁹ ; rescinded safety goal ³⁰ only to reinstate it 7/1/2011 ³¹	Carefully consider potential adverse unintended consequences before making new rules or regulations; conduct interviews and observations of users to gauge effects of rules and regulations on patient safety, quality of care, and clinician work-life
System Measurement and Monitoring - of system availability, use, effectiveness, and unintended consequences of system use	Incomplete or inappropriate (eg, combining disparate data) data aggregation leads to erroneous reporting	Increase measurement and monitoring transparency by providing involved stakeholders with access to raw data, analytical methods, and reports
	Incorrect interpretation of results	