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Technology-Induced Errors: Where Do They Come From and What Can We Do About Them?

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Abstract. The introduction of health information technology (HIT) has been associated with a decrease in medical error and this has been one of the main reasons for international efforts at increasing adoption of systems such as electronic health records, computerized physician order entry and clinical decision support systems. However, in recent years there is growing evidence that if not designed and tested properly such HIT can also lead to new categories of errors that were previously unseen in healthcare. These errors are known as technology-induced errors and they typically manifest themselves in the complex interaction between healthcare providers and HIT during real clinical use. In this paper the author explores the concept of technology-induced error in healthcare and discusses a range of strategies for detecting and mitigating such errors. Strategies include creating new organizations whose focus is to reduce technology-induced errors, develop and deploy new ways to detect such errors before systems are released, as well as approaches to reporting such errors after they occur. Other strategies include the development of regulation and policy to reduce such errors. It is argued that a multi-faceted approach to dealing with technology-induced error is needed.

Keywords. health information technology, technology-induced error, patient safety, risk management, quality improvement

Introduction

Internationally, we have seen the number of reports of technology-induced errors increase. Researchers from around the world (e.g. Australia, Canada, Denmark, Japan, Saudi Arabia, United States of America, United Kingdom) have documented instances where technology-induced errors have occurred in their respective countries [1, 2]. Researchers and policy makers are expecting this problem will grow in magnitude as the number of health information technologies (HIT) that are used to support consumers and health professionals continues to increase [1-3]. In an effort to address this expanding international problem, researchers are examining varying aspects of this emerging HIT safety concern to identify solutions. Identifying and solving technology-induced errors is essential as improving the quality and safety of HIT will lead to long term improvements in HIT. In this paper the author outlines the current state of HIT

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safety research and suggests a framework and strategy for going forward into the future to improve the quality and safety of systems.

1. Background

In 1999 the Institute of Medicine published "To Err is Human". The authors of the report identified that 770,000 patients die or are injured in hospitals annually from medical errors in the United States. The report was seminal from a healthcare industry perspective: (a) it acknowledged that medical errors were a significant quality and safety issue, and (b) it proposed a number of forward thinking solutions to address the problem. Among the solutions that were recommended by the authors of the report, were the introduction and use of HIT such as physician order entry systems, medication administration systems and clinical documentation systems by health professionals in healthcare organizations (e.g. hospitals, physician offices) [4]. Based on the findings of the report, researchers and policy makers in the United States concluded HIT could be used to reduce the number of medical errors that were occurring across healthcare organizations and healthcare systems [4, 5].

Policy makers around the world took note of the report and its findings [4]. Internationally, there emerged an impetus and desire to use HIT to effectively reduce medical errors. Around the world, this led to government policies aimed at increasing the rate of adoption of HIT among consumers, health professionals and/or healthcare organizations. Policy makers developed government programs aimed at modernizing and improving the safety of healthcare (e.g. United Kingdom (NHS), Canada, United States, European Union) by incentivizing the introduction of electronic health records [6-9]. As a consequence, internationally there has emerged a major trend towards adopting electronic health records and other HIT [6-9]. The introduction of such government programs led to a corresponding rise in the number of HIT implemented in healthcare settings [10-13]. With the move from paper as the primary medium for documenting patient care to the use of HIT to support citizen, patient, health provider and healthcare organizational activities and processes, a new type of error emerged: the technology-induced error [13-26]. In the early to mid 2000s published research documented the existence of several differing types of technology-induced errors thereby signaling the need to attend to the quality and safety of HIT [17-20, 22].

2. What are Technology-Induced Errors?

From a definitional perspective technology-induced errors have their origins in the: (a) design and development of a technology, (b) implementation and customization of a technology, and (c) interactions between the operation of a new technology and the new work processes that arise from a technology's use" [13, p. 154]. They also include errors that arise from poor systems' interfacing between HIT such as health information systems (e.g. physician order entry systems and pharmacy systems) and the devices that are used along with them (e.g. bar code readers) [14-16]. Technology-induced errors typically do not manifest themselves until HIT are used in complex healthcare settings and contexts involving real-world interactions with health providers and patients [24]. Some technology-induced errors also go unnoticed by their users (and are therefore not corrected by health professionals) [19]. They therefore differ

from many types of software and medical device errors that can be detected through conventional computer software testing such as black and white box testing [14].

Early works in this area described these types of errors. For example, Koppel and colleagues, employed a mixed method approach (i.e. qualitative and quantitative) using surveys, interviews, focus groups and observations to identify several differing types of technology-induced errors arising from the use of an electronic health record system. In their work the researchers found that 75% of housestaff (i.e. physicians) observed a technology-induced error at least once a week and sometimes more often. The researchers observed information and human-machine interface errors that did not match usual behaviours or work organization [20].

Others focused on developing qualitative and quantitative approaches to identifying technology-induced errors both before and after HIT release in real-world settings [17]. For example, Kushniruk and others employed usability testing techniques in their study of prescribing software installed on a mobile device prior to systems release. The researchers asked representative users to undertake representative tasks (i.e. prescribing medications). Users (i.e. physicians) were asked to prescribe medications using mobile device software while at the same time commenting on the usability of the interface features and functions. The researchers noted a relationship between technology-induced errors and the usability of specific user interface features and functions (e.g. small display, lack of visibility etc.). They noted that there was a high probability that a technology-induced error would occur if a serious usability problem was present [19].

Campbell and colleagues employed a qualitative, ethnographic approach in their study of health professionals' use of a HIT after it had been released [21]. In their work they identified nine categories of unintended consequences that may arise from a HIT's introduction to a healthcare organization, that include: "more/new work for clinicians, unfavorable workflow issues, never ending systems demands, problems related to paper persistence, untoward changes in communication patterns and practices, negative emotions, generation of new kinds of errors, unexpected changes in the power structure and overdependence on the technology" [21, p. 547]. These "new kinds of errors" (i.e. technology-induced errors) involve problematic interface designs and workflows as well as poor coordination between deployments of test, training and production versions of HIT [21].

Since then, several researchers have examined technology-induced errors and connected them with death, disability and mortality. Han and colleagues documented an increase in child mortality in a pediatric, acute care setting following the implementation of a Computerized Physician Order Entry System (CPOE). They noted that the "mortality rate significantly increased from 2.80% (39 of 1394) before CPOE implementation to 6.57% (36 of 548) after CPOE implementation" [18, p. 1506]. The researchers suggested that there is a need to evaluate the effects of HIT on mortality, post-implementation [18]. In follow-up to this research, Magrabi and colleagues studied data collected by incident reporting systems in two different countries: Australia and the United States. Their work validated prior work documenting the existence of technology-induced errors that may lead to harm, disability and death. Furthermore, their work classifies technology-induced errors into those errors that have their origins in human-computer and technical issues [23, 24]. In summary, over the past few decades we have seen a significant shift in how we view HIT – from HIT being used as a method for improving the quality and safety of healthcare to that of HIT quality and safety being called into question.

3. Towards a Framework and Strategy for Managing Technology-Induced Errors

Technology-induced errors are a significant public health issue as they represent one type of medical error [14, 26, 27]. In the research literature medical errors are considered a public health issue [26, 27]. As the number of HIT used by consumers, health professionals and healthcare organizations grows, there is a need to develop a comprehensive, global strategy to ensure the quality and safety of HIT and reduce the number of technology-induced errors that are occurring. We know that healthcare is a complex industry. Over the past several decades there has been an emphasis in the healthcare literature upon improving the quality and safety of healthcare using process technologies such as physician order entry systems, medication administration systems, bar coding administration systems, and clinical documentation systems [25, 28, 29]. These process technologies have now become the HIT backbone or organizational structures that many healthcare organizations rely on to help healthcare workers provide patient care [25, 28, 29].

Key thought leaders in the area of healthcare quality have found that the quality and safety of healthcare is influenced by an organization's structures, processes and outcomes [28-30]. For example, Donabedian's Framework [30] can be used to guide the development of a strategy for managing technology-induced errors within healthcare organizations and across a healthcare system. According to Donabedian [30], quality is composed of three dimensions: structure, process and outcome (see Table 1 for corresponding definitions and examples).

Table 1. Quality Dimensions

Quality Dimension	Definition	Example
Structure	Structure refers to the characteristics or attributes of the organization [28-30]	The organization implements a safe physician order entry system [28-30]
Process	Process refers to how organizations deliver, provide and manage patient care [28-30]	The physician order entry system is used by physicians to order patient medications [28-30]
Outcome	Outcomes focus on the impact of organizational processes upon patient health status [28-30]	There is a reduction in the number of medical errors resulting from drug-allergy interactions [28-30]

Figure 1 is an adaptation of Donabedian's [30] well known model of quality improvement as modified by the author to the context of technology-induced errors in healthcare. From Figure 1 we can see that there may be a number of organizational structures in place that may be important or relevant when considering technology-induced errors. As shown in Figure 1, these ***organizational structures*** could include the creation of a new national or regional organization that would be responsible for reporting systems, regulation [33] and certification [31], surveillance as well as having warning and alerting systems in place for technology-induced errors. Also as shown in Figure 1 a number of ***processes*** could be involved in mitigating technology-induced error. These could include processes for reporting on such errors by consumers, health professionals, healthcare organizations and vendors. Other processes include applying methods for testing HIT safety [32, 34], encouraging vendor development and design of safe interfaces and workflows [14, 19, 32], processes for reporting on the emergence of patterns of technology-induced errors and alerting consumers and health professionals about unsafe HIT features, functions and contexts of use. Finally, there

are a number of **outcomes** from these processes that would benefit healthcare. These include the reduction in technology-induced errors, improvements in design, development, implementation and maintenance of HIT and generally producing safer HIT [14]. Appropriate organizational structures need to be in place in order to support improved processes, and improved processes are needed to lead to improved outcomes (e.g. reductions technology-induced errors and improved HIT safety) as shown by the arrows in Figure 1.

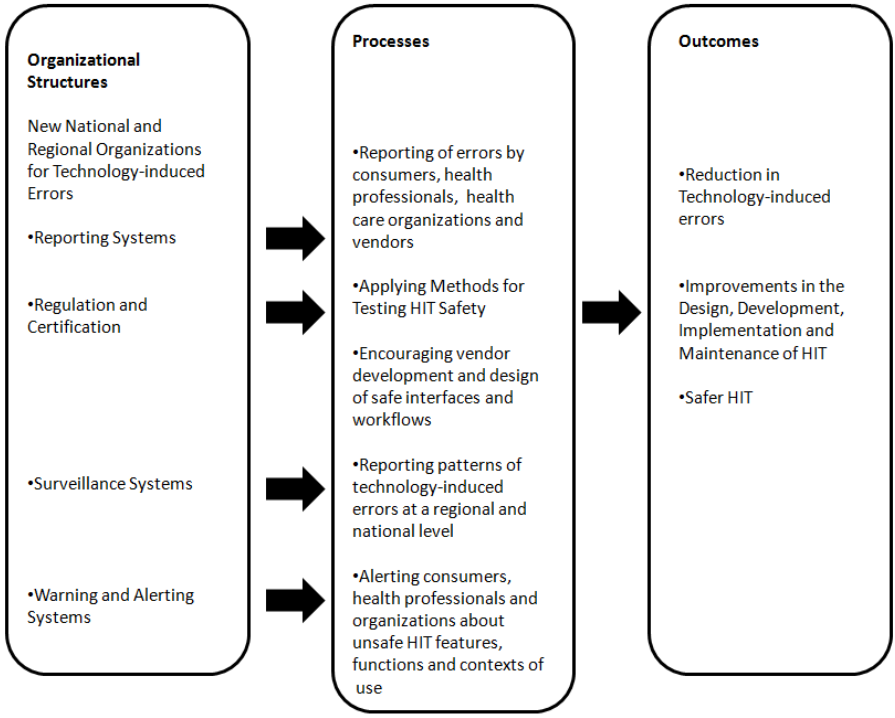

Figure 1. Structures, Processes and Outcomes: From Technology-Induced Errors to HIT

4. Conclusion

With time and investment, the healthcare industry (e.g. vendors, regional health authorities) can work towards reducing the number of technology-induced errors. In other industries the quality improvement literature has led to the production of more error free products and improvements in the safety of products (e.g. automobile industry, aviation industry, nuclear power industry). Such improvements are necessary in healthcare in the area of HIT design, development, implementation and maintenance. To date, health informatics professionals and researchers have acknowledged the existence of these types of errors, developed models and frameworks for understanding them, and developed methods for preventing and investigating errors. There is a need for the health care industry to develop new organizational structures to carry this work forward. There is also a need for national and regional organizations that are accountable for collecting data about technology-induced error. Such organizations

need to be able to regulate and certify industry developed HIT. Surveillance systems are needed to report on patterns of errors occurring across regions or contexts, and consumers, health professionals and healthcare organizations that use HIT should be alerted and warned about potential technology issues. Along with those warnings, solutions or interim risk mitigation measures should be provided. If we engage in these activities at a regional and national level and extend this work to the international milieu we will be able to reduce the number of technology-induced errors, improve the quality of HIT and in the long term develop safer HIT. Governments and policy makers need to apply this knowledge to the improvement of HIT quality and safety and create organizational bodies that are accountable for such errors. The future of HIT safety will involve individuals across the industry working across contexts: countries, healthcare systems and vendor organizations (much as is done in aviation). The goal will be to improve the quality and safety of HIT – as it is now a global problem that will continue to be an issue until national and regional governments develop and implement an international strategy for addressing technology-induced errors.

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