Qualitative Study of Technology-Induced Errors in Healthcare Organizations

by

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BSc, University of Victoria, 2011

A Thesis Submitted in Partial Fulfillment
of the Requirements for the Degree of

MASTER OF SCIENCE

in the School of Health Information Science

Supervisory Committee

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Abstract

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Health information technology is continuously changing and becoming more complex and susceptible to errors. It is both an essential and disruptive innovation that requires proper management of risks arising from its use. To properly manage these risks, there is a need to, first, determine how healthcare organizations in Canada are addressing the issue of errors arising from the use of health information technology (i.e., technology-induced errors). The purpose of this thesis is to determine the level of technology-induced error awareness in Canadian healthcare organizations, to identify processes and procedures at these organizations aimed at addressing, managing, and preventing technology-induced errors, as well as to identify factors that contribute to technology-induced errors. The study finds that, based on the currently available literature, information about these errors in healthcare is not complete. This prevents the development and application of effective health information technology risk management solutions. The research from the semi-structured interviews finds that the definition of technology-induced errors is not consistent among the study participants. The research from the semi-structured interviews also finds a lack of consensus on factors that cause technology-induced errors as well as a lack of reporting mechanisms available that are specifically aimed at reporting technology-induced errors in healthcare. This confirms

that there is a lack of technology-induced error awareness among Canadian healthcare organizations, which prevents the ability to properly address, manage, and prevent these errors.

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Acknowledgments

I would like to express my gratitude and appreciation to my supervisor, Dr. Elizabeth Borycki, for inspiring my interest in a particular health informatics research area. I would also like to thank her for her patience, ongoing support, and encouragement throughout the graduate process.

I would like to express my gratitude and appreciation to my committee member, Dr. Andre Kushniruk, for his guidance and ongoing support.

I would also like to extend a special thank you to the study participants for their insights and time.

Chapter 1: Introduction

1.1 Introduction

Information Technology (IT) is rapidly becoming one of the biggest drivers of industries, markets, and organizations worldwide. As a result, failures in technology can greatly impact the economy (Symantec Corporation, 2008). Research has shown that in 2009, only 32% of all software development projects were successful (i.e. were delivered on time, were delivered on budget, and met the requirements), 44% were unsuccessful (i.e. were not delivered on time, were not delivered on budget, and/or did not meet the requirements), and 24% resulted in complete failures (i.e. were cancelled prior to completion or were not used after completion) (Barr, 2011). Managing risks in IT projects should be an imperative for every business because IT failures affect not only the business directly, but the customers, suppliers, and partners as well. IT risks should be managed on a continuous basis by people, processes, and technology while ensuring that business objectives are met. Risk management allows IT services to be flexible and adapt to changes in the business climate (Symantec Corporation, 2008).

IT in healthcare has dramatically changed over the past few decades and has become increasingly more pervasive, complex, and susceptible to errors (Shortliffe & Blois, 2006). In addition, advances in health IT contribute to the complexity of health systems where medical devices are interconnected with the help of IT, creating systems of systems (Grimes, 2011). Health IT is also being viewed as both “an essential organizational prerequisite for the delivery of safe, reliable, and cost-effective health services” and “a disruptive innovation for health services organizations [that] remains an

overlooked organizational development concern" (Palmieri, Peterson, & Corazzo, 2011, p. 287). As a result of this complexity, risks arising from the use of health IT must be properly managed and methods/guidelines must be determined individually, aiding risk managers in the improvement of safety of healthcare systems. Effective risk management techniques must be applied in order to identify possible risks and properly manage resources to address those risks (Grimes, 2011). In order to provide solutions to help improve the current health IT risk management processes and procedures related to technology-induced errors, there is a need to determine how different healthcare or health IT-related organizations are addressing and preventing technology-induced errors as part of their current health IT risk management strategies and mandates. The purpose of this research is, therefore, to determine the degree of technology-induced error awareness in various Canadian healthcare organizations, and to identify those processes and procedures that are currently in place in various healthcare organizations to help address, manage, and prevent technology-induced errors. In addition, this research is aimed at identifying success factors and pitfalls that contribute to technology-induced errors based on the experiences of healthcare managers, administrators, and health IT professionals in order to share the findings with the healthcare organizations that strive to reduce the risk of future technology-induced-error occurrences.

1.2 Technology-Induced Errors

While health IT can be viewed as a solution to medical errors (Al-Assaf, Bumpus, Carter, & Dixon, 2003; Bates et al., 1998; Barber, Rawlins, & Franklin, 2003; Edwards & Moczygemba, 2004; Saathoff, 2005; Shortliffe & Cimino, 2006; Simpson, 2004), some of the opposing views have suggested that IT may actually hinder the attempt to reduce

medical errors or even introduce a new kind of error (Ash, Berg, & Coiera, 2004; Goldstein et al., 2001; Horsky, Zhang, & Patel, 2005; Randell, 2003; Vicente, 2003). The Institute of Medicine report released in 1999 (National Research Council, 2000) has significantly changed the view on how medical errors should be acknowledged, addressed, reported, and prevented as well as on the patient safety related literature in general. Since the release of the report, various articles and studies have attempted to find a solution for improving patient safety through elimination or reduction of medical errors (Al-Assaf et al., 2003; Barber et al., 2003; Edwards & Moczygemba, 2004; Saathoff, 2005; Simpson, 2004). One of the main solutions proposed has been IT, or, specifically, computerized physician order entry (CPOE) (Saathoff, 2005) and the electronic medical record (EMR) (Edwards & Moczygemba, 2004). While various articles have attempted to prove the positive effects of these solutions, a different trend in the literature has emerged (Ash et al., 2003; Goldstein et al., 2001; Horsky et al., 2005; Randell, 2003; Simpson, 2005; Vicente, 2003). Some researchers have argued that IT not only did not provide a solution for reducing medical errors, but it actually facilitated/induced new ones (Borycki & Kushniruk, 2005; Koppel et al, 2005). A new type of error in healthcare that arises from the use of technology was identified and defined as an "error that inadvertently occurs as a result of using a technology" (Carvalho, Borycki, & Kushniruk, 2009, p. 54), and "arise[s] from: a) the design and development of technology, b) the implementation and customization of a technology, and c) the interactions between the operation of a technology and the new work processes that arise from a technology's use" (Borycki & Kushniruk, 2008, p. 154). The Institute of Medicine released another report in 2011 that focused on patient safety and health IT, stating that "poorly designed, implemented, or

applied, [health IT] can create new hazards in the already complex delivery of health care", resulting in the need for workarounds and increased workloads, which, in turn, may cause harm (National Research Council, 2012, p. 22).

As a result of this new type of error emerging in the field of health IT, health IT risk management strategies must be adapted to encompass the ability to identify the need to bring continuously increasing awareness to this new type of error and include such errors into overall health IT risk management directives as conducted by organizations.

1.3 Problem Statement

As mentioned previously, IT is being introduced in healthcare settings in hopes of improving healthcare quality and outcomes (Edwards & Moczygemba, 2004; Saathoff, 2005). Articles and studies have been published since the report by the Institute of Medicine released in 1999 (National Research Council, 2000) in hopes of finding a solution for improving patient safety, specifically, through the reduction and elimination of medical errors. IT, and, particularly, the CPOE and the EMR have been proposed as some of the solutions to the issue (Edwards & Moczygemba, 2004; Saathoff, 2005). Recently, however, some researchers began to argue that while such IT does have the capability to improve patient safety and health outcomes, it actually enables a new kind of error to occur. As a result, a new term was introduced that defined a new type of error in healthcare arising from the use of technology (Borycki & Kushniruk, 2005; Koppel et al., 2005).

Technology-induced errors are errors that result from using information systems in complex settings and environments in healthcare (Borycki & Kushniruk, 2005). Such negative impacts of technology not only affect patients, but healthcare providers and

organizations as well (Borycki & Kushniruk, 2005). The risk of technology-induced errors can increase from the implementation of IT in healthcare settings. Healthcare organizations, therefore, must be made aware not only of the concept of technology-induced error, but of the factors that contribute to the increased risk of such error occurrence in order to properly manage it. All stakeholders in healthcare should be aware of the risk of technology-induced errors, including patients, healthcare providers, healthcare managers, and software vendors. It is, therefore, important to identify the factors that drive the occurrence of technology-induced errors, and, hopefully, reduce such risk as a result of increased awareness. In Canada, an increasing number of health IT systems are being implemented in healthcare organizations, including hospitals and physician offices (Rozenblum et al., 2011). It is unclear whether the incidence of technology-induced errors is currently increasing. Regardless, it is also unclear how various healthcare organizations are actually addressing this problem, and, moreover, if they are even aware of the problem. There is a gap in the literature regarding how organizations manage technology-induced errors. Such information is needed as it would enable a better initiative for problem-solving and guidance as part of the health IT risk management in order to reduce, eliminate, and prevent technology-induced errors. As a result, there is a need to explore how organizations are addressing technology-induced errors so that other organizations may learn from these experiences and reduce the risk of future occurrences of technology-induced errors.

1.4 Research Objectives

The purpose of this research project is to identify technology-induced error management processes and procedures that are currently being used by various Canadian

healthcare organizations, including success factors and pitfalls that contribute to technology-induced errors. The objectives of this research are, therefore, to:

- Determine if leaders at various Canadian healthcare organizations are aware of the technology-induced error concept, risks associated with it, and its potential impact on patient safety;
- Identify factors within various Canadian healthcare organizations that contribute to the incidence of technology-induced errors;
- Determine if various Canadian healthcare organizations have processes and procedures in place to identify, address, report, rectify, and prevent technology-induced errors; and
- Determine whose responsibility it is to address technology-induced errors.

1.5 Research Questions

The specific questions to achieve the research objectives were:

1. Are healthcare organizations in Canada aware of the concept of technology-induced error?
2. Do healthcare organizations in Canada know where technology-induced errors come from or what causes them?
3. What factors contribute to the incidence of technology-induced errors?
4. Do healthcare organizations in Canada have specific processes and procedures in place to identify, address, report, rectify, and prevent technology-induced errors?
5. Who is responsible for addressing this issue?

The qualitative approach of content analysis was used to answer these questions. To obtain answers to the research questions, research participants were interviewed. The background for the study, including the current state of knowledge in the area of technology-induced errors, was explored by conducting a literature review about technology-induced errors. The following section will present this literature review as well as the discussion about technology-induced errors.

Chapter 2: Technology-Induced Errors in Healthcare

2.1 Importance of Technology-Induced Errors

It is estimated that out of approximately 2.5 million hospital admissions in Canada annually, 185,000 are related to adverse events resulting in death, disability, and prolonged hospital stay (Baker et al., 2004). Approximately 65,000 (35%) of those adverse events are potentially preventable (Baker & Norton, 2004). The report by the Institute of Medicine (National Research Council, 2000), published almost a decade ago, has made a significant impact not only on the importance of acknowledging, addressing, reporting, and preventing adverse events, but on a range of patient safety related literature as well. The Institute of Medicine estimated that in the United States, somewhere between 44,000 and 98,000 Americans die each year as a result of medical errors (Charatan, 1999). Numerous articles and studies have been published since then attempting to find a solution for improving patient safety especially by eliminating or at least reducing the rates of medical errors (Al-Assaf et al., 2003; Barber et al., 2003; Edwards & Moczygemba, 2004; Saathoff, 2005; Simpson, 2004). One proposed solution for patient safety has been information technology (IT) (Bates et al., 1998; Bates & Gewande, 2003; Shortliffe & Cimino, 2006; Tierney, 2001), such as the computerized physician order entry (CPOE) (Bates et al., 1998; Saathoff, 2005), decision support systems (DSS) (Bates et al., 1998), medication administration systems (Bates et al., 1998), and the electronic health record (EHR) (Edwards & Moczygemba, 2004). Unfortunately, subsequent research has found that in some cases health IT did not actually reduce medical errors (Ash et al., 2003; Ash et al., 2004; Beuscart-Zephir et al.,

2005; Goldstein et al., 2001; Han et al., 2005; Horsky, Kuperman, & Patel, 2005; Horsky, Zhang, & Patel, 2005; Randell, 2003; Simpson, 2005; Vicente, 2003), but, in addition, introduced a new type of error or resulted in unintended consequences. Ash et al. (2007b), for example, identified nine types of unintended consequences resulting from the use of CPOE: more/new work issues for healthcare providers, workflow issues, continuous hardware and software change demands, paper persistence issues, communication issues, negative emotions, new kinds of errors, changes in the power structure, and overdependence on technology. Similarly, other researchers discovered that health IT may actually facilitate or induce a new type of error (technology-induced error) that arises from poorly designed technology or from the interaction with technology (Ammenwerth & Shaw, 2005; Brown et al., 2008; Horsky, Kuperman, & Patel, 2005; Borycki & Kushniruk, 2005; Koppel et al., 2005; Kushniruk et al., 2004), such as entering and retrieving information, communication, and coordination processes (Ash et al., 2004) as well as other sociotechnical interactions occurring as part of the organization's workflows, culture, social interactions, and technology (Harrison, Koppel, & Bar-Lev, 2007). Unintended consequences arise from technology use and "lack a purposeful action or causation" (Ash et al., 2007a, p. 415). Technology-induced errors, also referred to as e-iatrogenesis (Sittig & Singh, 2009), have been defined as unintended consequences (Ash et al., 2007a) that "arise from: (a) the design and development of technology, (b) the implementation and customization of a technology, and (c) the interactions between the operation of the new technology and the new work processes that arise from a technology's use" (Borycki & Kushniruk, 2008, p. 154). Technology-induced errors differ from medical errors in that medical errors arise from the failed

process of medical management resulting in adverse events whereas technology-induced errors arise from technology and humans' interactions with technology resulting in unintended consequences (Borycki, Kushniruk, & Brender, 2010). Even though Magrabi et al. (2010) proposed a health IT-related error classification scheme for such error reporting systems, which was later improved by identifying additional categories in 2012 (Magrabi et al.), Borycki and Keay (2010) brought attention to the fact that there is a lack of effective error-reporting systems on national and regional levels that would enable health professionals to report near-missed and actual errors resulting from health IT and medical device use. There are some reporting systems in the United States, such as the Food and Drug Administration's (FDA) Manufacturer and User Facility Device Experience (MAUDE) database, which allows for reporting of health IT-related problems (Magrabi et al., 2012) as well as the FDA-supported Medical Device Reporting (MDR) and Medical Product Safety Network (MedSun) database, which can expose problems related to health IT in terms of "missing or incorrect data, data displayed for the wrong patient, chaos during system downtime and system unavailable for use" (Myers, Jones, & Sittig, 2011, p. 1). These databases, however, are not designed specifically for health IT-related error reporting, "which may lead to underreporting and need for development of new error reporting approaches and mechanisms focused around health IT problems" (Kushniruk, Bates, Bainbridge, Househ, & Borycki, 2013, p. 4). Furthermore, some research suggests that there is not only a lack of awareness of technology-induced error occurrence among health professionals (Borycki & Kushniruk, 2008; Kushniruk et al., 2005), which may also lead to underreporting and greater impediment on patient safety overall, but also a lack of "acceptable definitions of health IT-related errors" and a lack of

clarity when it comes to measuring or analyzing health IT-related errors (Sittig & Singh, 2011, p. 1279).

2.2 Factors that Contribute to Technology-Induced Errors

2.2.1 Human Error Analysis: How Does Human Error Relate to Technology-Induced Errors?

It has been suggested that error occurrence can be understood by examining the organization and processes within that organization rather than shifting the blame for errors on humans (Woods & Cook, 1999; George, Rowlands, & Kastle, 2004).

2.2.1.1 Human Error

The concept of human error has been studied thoroughly in the field of cognitive psychology, but only recently has it entered the field of healthcare. Reason (2000) identified the two different kinds of error that has significantly influenced the field of human factors and the way human errors have been looked at since then. The author suggested that errors may come from the sharp end (i.e., the front line) as well as from the blunt end (i.e., organizational structure and management). This helped initiate a shift in the "blaming culture", which until then focused on assigning blame to the front line personnel (i.e., clinicians) rather than addressing the overall organizational structure, especially as it related to systems fit within a particular workflow. St. Pierre, Hofinger, and Buerschaper (2008) suggested that even highly motivated and experienced people make serious errors. In addition, certain human errors that result from the use of information technology, such as a "use-error", can be predicted and prevented with the help of human factors. This type of human error can be caused by poor system design,

inadequate training, and poor understanding of user tasks and workflow (VA National Center for Patient Safety, n.d.).

2.2.1.2 The Swiss Cheese Model: Background, Healthcare, and Health IT

The Swiss Cheese Model of human error was introduced by James Reason almost 15 years ago. It has quickly evolved and has become very well known for its important contributions within the fields of aviation, engineering, human factors, healthcare, and risk management. While the model has received numerous criticisms, it has dramatically impacted the way that both the front-line workers and managers/decision makers within these disciplines look at human errors, their origins, and the reasons why they occur in the first place. As a result of the Swiss Cheese Model, the need has been identified to hold accountable not only the front-line workers at the sharp end, but to ensure that a system as a whole is properly analyzed and assessed at the blunt end in order to ensure error reduction. In healthcare settings, the model has acted as an aid to help shift the blame away from the doctors, nurses, and other clinicians to consider workplace settings and management as contributing factors that have the power to improve or decrease patient safety (Reason, 2000). It has also provided a way to look at errors in healthcare arising from technology use (i.e., technology-induced errors) (Borycki et al., 2009a).

In order for an accident to occur in a complex system, such as healthcare, for example, Reason (1995) concluded that multiple factors must be present and active simultaneously. These factors may arise as a result of impaired staffing, training policy, communication patterns, hierarchical relationships, and, even, managerial decisions. While most of the time such factors are present at any given complex system, they are not always active concurrently. Reason provided a distinction between active errors and latent conditions.

He defined the latent conditions as being constantly present in a system and triggered before the occurrence of an accident, i.e., inevitable "resident pathogens" (Reason, 1995; Reason, 2000; Reason, Hollnagel, & Paries, 2006). Reason defined active failures as slips, lapses, mistakes, and violations that occur as a result of those who are in direct contact with a system at the sharp end, i.e., front-line staff (Reason, 2000). The author also suggested that errors (or holes) may occur in any of the five levels, including top level decision makers, line management, preconditions, productive activities, and defenses, and that these "holes" need to align in order for an accident to occur (Reason et al., 2006). Defenses, barriers, and safeguards can be put into three different categories: engineered defenses, such as alarms, physical barriers, and automatic shutdowns; defenses that rely on people, such as surgeons, anaesthetists, pilots, and control room operators; and defenses that depend on procedures and administrative controls (Reason, 2000).

Reason suggested that three basic elements must be present in any model of accident causation: hazards, defenses, and losses. Since distinguishing productive and protective system elements is often difficult, the model acknowledged barriers, defenses, safeguards, and controls that may be present in any given system. Reason also explained the occurrence of the holes, gaps, or weaknesses. The author differentiated between short-term faults arising in the front-line and long-term faults arising from system designers, managers, and support, i.e., latent conditions that exist in all organizations (Reason et al., 2006). Reason's Swiss Cheese Model introduced a new way of looking at accidents and their occurrence as a result of the interrelation of factors, or conditions, that contribute to the holistic view of any organization or system. Reason (2000) suggested to

view the human error problem from two perspectives, i.e., from the person perspective and from the system perspective. The main focus of the person approach is on the people performing unsafe actions at the sharp end, such as nurses, physicians, and pharmacists, that arise as a result of mental processes such as forgetfulness, poor motivation, and negligence. According to Reason, the person approach has been "the dominant tradition in medicine" (Reason, 2000, p. 768). Reason suggested that it is crucial to have proper error reporting mechanisms in place to thoroughly analyze accidents and errors in order to be able to predict future occurrences. Reason has discussed two main criticisms of this approach. The first criticism was concerned with the fact that "it is often the best people who make the worst mistakes"; the second criticism was concerned with the fact that "far from being random, mishaps tend to fall into recurrent patterns" (Reason, 2000, p. 769).

The main focus of the system approach is on the failed systems defenses rather than the failed human performance, and the expectation that errors are bound to occur in every organization. In this approach, errors are seen as consequences rather than causes, and that the working environment rather than the human condition must be changed in order to prevent these errors. According to Reason (2000), it is crucial to pay attention to the following five factors when taking the systems approach: person, team, task, workplace, and institution (p. 769). Furthermore, many other factors may contribute to medical error, including organizational, ergonomic, situational, and external factors, human vulnerabilities, and cognitive lapses (Kadzielski & Martin, 2001).

Each of these perspectives contributed to a different model of error causation, which, in turn, suggested different ways of managing errors. It is important to understand these different perspectives in order to properly address the issue of accidents in healthcare and

ensure patient safety. Furthermore, in order for accidents to occur, holes must arise in the defense layers. Such holes arise both as a result of active failures and latent conditions (Reason, 2000).

The Swiss Cheese Model has become very popular in healthcare settings almost since its inception, but its popularity reached new heights when the report from the Institute of Medicine was released in 1999, calling for action to address and rectify the ever-increasing issue of adverse events and medical errors (National Research Council, 2000). In addition, the study by Hallam provided significant insights into declining people's trust and confidence in the care they receive and the ability of healthcare providers and institutions to truly "do no harm" (Hallam, 2000).

According to Kadzielski and Martin (2001), the goal of "zero defects/errors" in healthcare is an unrealistic goal, as errors are bound to occur. But understanding the errors and enhancing recovery mechanisms should aid in reducing the frequency and severity of such errors. In other words, incorporating more slices of the "Swiss Cheese" (i.e., checks and balances) into medical error management should aid in ensuring that such errors do not reach the patient. In addition, the authors added two types of errors to the existing active and latent errors proposed by Reason. They identified an execution error that results from not completing a planned action and a planning error that results from incorrect intended action. Furthermore, the authors stressed that it is crucial to move away from the "blaming culture" of healthcare where the ever-increasing trust in the system increases the need to blame someone and the ever-increasing fear of litigation decreases the reporting and discussion of medical errors in general (Kadzielski & Martin, 2001). According to Borycki et al. (2010), "models of error cannot be easily imported

[from other industries such as aviation, nuclear power, or banking] into healthcare due to the unique features of the setting and in some cases these models require modification or extension" (p. 715).

2.2.2 What Causes Technology-Induced Errors?

Borycki and Kushniruk (2008) identified many sources of blunt-end errors related to health IT, such as different points in the systems development life cycle and lack of understanding of healthcare processes during the systems development life cycle, as well as errors arising from organizational processes such as implementation, customization, and policies related to actual use. Keay and Kushniruk (2009) developed a framework aimed at identifying blunt-end causes of technology-induced errors in healthcare. Borycki et al. (2009a) extended Reason's model to health informatics by presenting a "new framework for diagnosing technology-induced errors" (p. 184). The authors suggested that "the causes of error can be located on a continuum from blunt end causes [...] to sharp end causes" (p. 184). Borycki et al. (2009a) stated that the current health informatics literature has identified the need to "understand the potential root causes of technology-induced errors" (i.e., errors arising as a result of using technology) as well as to assess policies, processes, and similar events that contribute to the occurrence of technology-induced errors (p. 183). The authors have identified the need to move away from the sharp end of technology-induced errors and focus more on the blunt end of these errors (i.e., errors arising from software development and implementation of systems and devices). They suggested that one must consider various organizational influences when attempting to understand technology-induced errors at the blunt end, and identify "blunt sources of sharp end error" (Borycki et al., 2009a, p. 184). In the new framework

(Borycki et al., 2009a), the authors argued that in addition to an individual, technology-induced errors might arise within four or more organizations that make up healthcare systems:

1. the governmental organizations that develop policies that govern technology requirements;
2. the model organizations for which the software is initially designed and developed (Orlinkowski, 1992);
3. the vendor organizations that design, develop, and test the software; and
4. the local organizations that customize and implement the software and train their employees.

Following this study, Borycki et al. (2010) conducted follow-up studies that aimed to analyze errors occurring along the entire continuum from the blunt end to the sharp end. The authors were able to both trace back to identify blunt end causes after error occurrence at the sharp end and analyze potential errors by starting the analysis at the blunt end and moving to the right side of the continuum toward the sharp end.

Borycki, Kushniruk, Kuwata, and Kannry (2011) suggested that technology-induced errors may arise on two levels of EHR-user interaction. Level 1 refers to the basic level of interaction, where a user interacts with a system in isolation. Level 1 interaction focuses on user interface design. Level 2 refers to user interaction with an EHR within the complex work context, resulting in, for example, a three-way interaction among a doctor, a patient, and an information system (Borycki et al., 2010).

In summary, the role of and the intention of introducing IT in healthcare has always been to reduce medical errors, and, in turn, increase patient safety. Unfortunately, recent

literature in this field has shown that health IT may actually hinder patient safety by introducing a new kind of error (i.e., technology-induced error). The solution for resolving this type of error is not, however, clear-cut. There are multiple factors that contribute to the occurrence of technology-induced errors, ranging from sharp end causes to blunt end causes. It is, therefore, vital to explore and to better understand the factors that contribute to technology-induced error occurrence.

2.3 Methods for Analyzing, Managing, and Preventing Technology-Induced Errors

Technology-induced errors can be detected and prevented by rigorously evaluating health IT systems under simulated conditions prior to their actual deployment using usability engineering methods (Borycki & Kushniruk, 2005). This has been shown in previous studies that aimed to assess the relationship between issues with a health IT system or a medical device and medical errors using methods such as usability inspection, where an analyst steps through the system and identifies potential issues, and usability testing, where representative users of the system complete representative tasks using the system, therefore allowing analysts to identify potential problems from a user's perspective (Baylis, Kushniruk, & Borycki, 2012; Kushniruk et al., 2004; Kushniruk et al., 2005; Kushniruk, Borycki, Anderson, & Anderson, 2008; Zhang, Johnson, Patel, Paige, & Kubose, 2003). Carvalho et al. (2009) have developed a set of evidence-based heuristics that can be used to assess the safety of health IT systems and identify technology-induced errors prior to system deployment. In addition, Kushniruk et al. (2010) has identified a framework for selecting most suitable systems and matching them to organizational workflows.

Borycki and Kushniruk (2009) identified two distinct types of health IT evaluation methods aimed at managing technology-induced errors: predictive and post-implementation. Predictive methods, such as heuristic evaluation, clinical simulation, and computer-based simulation, are used to "identify potential technology-induced medical errors prior to the [health IT system] implementation" in order to "prevent technology-induced errors or reduce the likelihood of their occurrence following deployment" (p. 285). Post-implementation methods, such as case studies, naturalistic observation, and ethnography, are used to identify technology-induced errors post implementation. Both method types have their own advantages and limitations, such as higher costs associated with fixing systems that are already in place (Patton, 2001) and a lack of realistic interaction when evaluating systems in laboratory settings (Borycki & Kushniruk, 2009). The authors, therefore, recommended a mixed methods approach, called scenario-based testing, in order to simulate a real-world setting yet aim to identify technology-induced errors prior to system deployment (Borycki & Kushniruk, 2009). Furthermore, Borycki et al. (2010) suggested that in order to predict and prevent technology-induced errors, one must combine methods from software engineering, human factors, organizational behaviour, and the Interactive Sociotechnical Analysis Framework, which helps to specify "important relationships among new health IT, workflows, clinicians, and organizations", and, therefore, to identify the potential for unintended consequences (Harrison et al., 2007, p. 543). In addition, Borycki and Kushniruk (2010) called for an integrated approach to evaluate health IT systems that combines cognitive and socio-technical methods through clinical simulations conducted at various stages of the systems development life cycle or the software customization processes. Borycki et al. (2009b)

suggested viewing simulations as "a critical element in risk management involving [health IT systems]" and as "a risk control measure to reduce adverse events in healthcare and any subsequent claims against the organization" (p. 91). Borycki et al. (2009b) and Kushniruk, Borycki, Anderson, and Anderson (2009) examined the effects of computer-based simulations in comparison to clinical simulations to predict the impact of health IT systems on healthcare organizations and patient safety through more effective risk management of technology-induced errors. In addition to such methods, Borycki and Keay (2010) identified the following three methods that could be used to diagnose technology-induced errors: "the use of ethnography after a HIS has been implemented, an extension of ethnography referred to as rapid assessment and the use of case studies after a technology-induced error has occurred" (p. 50).

In summary, there are various methods that aim to detect, manage, and prevent technology-induced errors. While some methods focus on prediction of such errors prior to system implementation in healthcare settings, others are aimed at identifying technology-induced errors post system implementation.

2.4 Risk Management and Current Challenges

Borycki et al. (2009b) suggested that risk management does not yet "have widespread use in [health information systems] except in the design of medical device software" (p. 91), although it is a well established tool for accountability in healthcare settings. The authors suggested that health IT risk management should "include simulation as a risk control for downstream errors involving technology", which, in turn, would "improve the implementation of [health information systems] and institute an accountability structure that is acceptable to decision-makers" (Borycki et al., 2009b, p. 91). Unfortunately,

according to Magrabi et al. (2010), “it is currently not possible to prioritize corrective strategies for safety-critical risks of health IT systems” because of “the lack of specific information about the underlying causes of computer-related incidents and the severity of their impact” (p. 663).

Kushniruk et al. (2013) have outlined current challenges that Canada is facing in terms of management of technology-induced errors. The researchers have identified the following factors that are currently affecting and will affect the issue of technology-induced errors in the near future (Kushniruk et al., 2013):

- current lack of collaborative effort within Canadian organizations to address the issue of technology-induced errors
- current lack of user-centered design principles among health IT vendors and their internal business processes
- difficulties ensuring the right system fit within Canadian organizations when it comes to health IT systems adopted from the United States
- current lack of error reporting systems that are designed specifically for reporting technology-induced errors as well as the lack of established technology-induced error reporting principles
- current lack of education and training specific to the ability to recognize and report technology-induced errors
- current classification of health IT software as medical devices, which increases the complexity of requirements put on health IT vendors

- current lack of international exchange of knowledge and lessons learned about technology-induced errors, especially among users of such systems that are available in various countries.

In summary, even though risk management in health IT is not widely practiced yet, an approach involving simulations has the potential to rectify technology errors in healthcare. Unfortunately, a lack of information regarding computer-related incidents in healthcare, and, specifically, their underlying causes, contribute to difficulties establishing and standardizing effective health IT risk management processes. Given the current and future challenges in Canada, it is clear that there is an urgent need to determine the level of technology-induced error awareness and understanding of its potential impact on patient safety among the leaders of different Canadian healthcare organizations. There is also a need to identify factors that contribute to such errors within various Canadian healthcare organizations to either confirm or expand the growing list of factors identified in the literature. Finally, given the aim to change the blaming culture in healthcare, there is a need to determine whose responsibility it is to address technology-induced errors, and how such errors are being or should be identified, addressed, reported, and rectified in various Canadian healthcare organizations.

Chapter 3: Research Approach

3.1 Methodology

Qualitative research aims to understand people's attitudes, experiences, perspectives, and understanding, and to reveal new ways of looking at and a new understanding about a phenomenon in question. In-depth interviews are a method of data collection for capturing participant perception of the world through events descriptions and explanations (Jackson & Verberg, 2007). Content analysis was the qualitative research approach used in this study. According to Holsti (1969), data from open-ended questionnaires or interviews can be best utilized by applying content analysis. Because the goal of the study was to understand how decision makers, managers, and individuals, who work with technology in healthcare organizations, address the issue of technology-induced errors, in-depth, semi-structured interviews were chosen for data collection and content analysis method was chosen for data analysis (Jackson & Verberg, 2007).

3.2 Standpoint

In order to address the concern of bias or personal assumptions, researcher's standpoint is addressed in this section. Since this project began as an undergraduate research study, the researcher did not possess a vast set of skills or knowledge related to technology-induced errors. While this may be seen as a limitation due to inability to identify oneself as an insider with the study participants, it may actually prevent from asking participants leading questions, and, therefore, influencing their answers. At the time that the study and the interview questions were constructed, the researcher had limited knowledge about technology-induced errors. This knowledge was attained as part

of the topic of technology-induced errors being presented in one of the undergraduate courses in health information science at the University of Victoria. This enabled the researcher to "take a new look through the lenses of [the] participants' eyes, and it also help[ed] to theorize" the results (Holloway & Biley, 2011, p. 972). In addition, in order to make sure that what participants said was understood properly by the researcher, the researcher often summarized participants' answers and asked to confirm if they were heard and understood properly. The researcher also often asked to clarify participants' answers or provide greater detail to their answers.

3.3 Participants

Convenience (accidental) sampling was chosen for the study in order to send invitations to the population that was already available as a result of access to the health informatics alumni and graduate studies mailing lists at the University of Victoria (Hart, 2007). It was expected that potential participants would reply to the invitation letter if they had experience with technology-induced errors or had the experience with working with health information systems in general. These academic mailing lists also provided an opportunity to recruit those participants who, by nature, would, more likely, be interested in contributing to a research study. The target populations for recruitment included healthcare managers, administrators, and health IT professionals. These populations were of interest because they were expected to have direct experience in working with issues related to technology-induced errors and have the experience of working with health information systems in general. Individuals with these experiences were expected to be able to explain the issue of technology-induced errors as well as to provide insights into the underlying reasons that might cause technology-induced errors

(Borycki et al., 2009a). The aim was to recruit at least 15 professionals from these areas or continue recruiting until saturation was reached. According to Bertaux (1981), 15 interviews are the smallest acceptable sample size for qualitative research in order to reach saturation. Furthermore, Mason (2010) identified a number of qualitative research studies that employed the method of content analysis, and the sample sizes in those studies ranged from 2 to 70 interviews. Saturation refers to the point in data collection, where participant's contributions mirror previously collected data (Jackson & Verberg, 2007). The data for this research study was, therefore, being collected until saturation occurred.

3.3.1 Inclusion Criteria

Participants were included in the study if they:

- were fluent in English
- had experience in/with any or all of the following:
    - healthcare management
    - healthcare administration
    - health IT
    - working with issues related to technology-induced errors.

Inclusion criteria were justified by expecting professionals with such experience to be knowledgeable about the topic of technology-induced error as a result of dealing with the issue as part of their daily work (Borycki et al., 2009a).

3.4 Recruitment

Participants were recruited by sending invitation letters to two health informatics mailing lists (Appendix A). Some participants were also recruited using the Snowball Sampling approach: once the initial round of participants were recruited via the mailing lists, they were asked to forward the invitation letter (Appendix A) to their peers and colleagues, who, possibly, would be interested in participating in the study as well (Jackson & Verberg, 2007).

3.5 Setting

Data for the study were collected by conducting telephone interviews. Among various reasons, there were two main reasons for choosing such an approach in this particular kind of research. First, this approach allowed the participants to take part in the study in the comfort of their homes, work offices, or other locations most convenient to them. Second, participants from different Canadian provinces were able to participate, since participation was not restricted to a geographic location of the researcher or the participants and eliminated the need for travel (Knox & Burkard, 2009). In addition, according to Knox and Burkard (2009), various other advantages exist for conducting telephone interviews as opposed to face-to-face interviews, such as:

- Reducing response bias due to the lack of ability to observe facial expressions, and
- Increasing anonymity, and, thus, enabling participants to be more open with their responses.

Finally, since no direct observations were involved in this research, face-to-face data collection was not necessary.

3.6 Data Collection

As mentioned previously, in-depth, semi-structured interviews were used for data collection. Such interviews are often audio-recorded in order to use direct quotations and verbatim explanations in data analysis and presentation of results (Jackson & Verberg, 2007). For the purpose of this research study, demographic questionnaires and in-depth, semi-structured interviews were used to collect two sets of data.

3.6.1 Consent

Due to the nature of telephone interviews, informed consent was acquired verbally from all participants at the beginning of each interview by reading out loud the verbal consent form to the participants (Appendix B). After reading the verbal consent form to the participants, they were asked to indicate their agreement or disagreement to participate in the study and were offered to have a copy of the verbal consent form emailed to them. They were explicitly informed that their participation in the study had to be completely voluntary and that they had the right to withdraw from the study at any time without any consequences to them. Consents from all 17 participants were obtained.

3.6.2 Demographic Data

Demographic questionnaire titled "Qualitative Study of Organizational and Legal Aspects Involving Technology-Induced Errors in Health Care Organizations: Background and Demographic Survey" was administered verbally at the beginning of each interview to ensure that the participants had the experience in healthcare management, healthcare administration, and/or health IT (i.e., the participants met the inclusion criteria) as well as to determine their areas of expertise and duration of experience in those areas and "to

discern any statistically significant differences in responses" (Appendix C) (Saldaña, 2011, p. 11).

3.6.3 Data from In-Depth, Semi-Structured Interview Questions

After the demographic questionnaire, the participants were asked to participate in an in-depth, semi-structured interview, titled "Semi-Structured Probes for Technology-Induced Error Study Interviews" (Appendix D). Each interview was expected to last approximately 30 to 60 minutes. Even though telephone interviews tend to be shorter than face-to-face interviews, it is common to conduct telephone interviews that last approximately 80 minutes, on average (Irvine, Drew, & Sainsbury, 2013). Semi-structured form of interviews was used to conduct interviews that allow for "follow[ing] topical trajectories in the conversation that may stray from the [questions] guide when […] appropriate" (Robert Wood Johnson Foundation, 2008). In-depth form of interviews was used because such interviews "provide a method for collecting respondents' perception of their world" and "solicit people's descriptions and explanation of events in their world" (Jackson & Verberg, 2007, p. 170). In addition, semi-structured interviews were used because they have the following strengths associated with them:

- the ability to simply and efficiently gather data that cannot be easily observed,
- the opportunity to discuss a topic in detail and depth,
- the opportunity to clarify complex questions or expand on answers given or issues raised by the participants,
- the ability to eliminate biasing responses as a result of involving only a few pre-determined questions and allowing the rest of the interview to flow freely, and
- the ability to easily audio-record (Sociology Central, 2011).

There are also certain limitations that result from semi-structured interviews. If an interview is too structured, the questions might actually make the participants give specific answers that will not be entirely true to the participant, i.e. they will be biased or "guided" by the interviewer to give answers the interviewer expects. At the same time, because these interviews are not overly structured, it is often difficult to repeat them, and problems with standardization arise. In addition, it is sometimes difficult to analyze the depth of qualitative information in semi-structured interviews. Finally, there is no way to find out if participants are lying or improperly recalling information (Sociology Central, 2011).

Even though the participants were aware that the interviews might last 30 to 60 minutes, the interviews were not restricted by time if the participants were willing to spend more time on answering questions. The interviews focused on the areas of organizational and legal aspects of technology-induced errors in healthcare in order to identify how healthcare organizations are identifying and addressing technology-induced errors. The interviews were audio recorded in order to preserve the exact verbatim of each participant and use quotes to illustrate certain points when disseminating results (Jackson & Verberg, 2007).

3.7 Data Analysis

Two types of data were analyzed: demographic data and data obtained from the semi-structured interviews.

3.7.1 Demographic Data Analysis

Demographic data were used to better inform the results from the semi-structured interviews in terms of participants' educational and professional background, areas of expertise and number of years active in those areas, as well as participants' exposure to different health IT systems. Demographic data were analyzed in terms of participants' age, gender, and number of years worked in health IT settings. Participant age and number of years worked in a particular area that they considered themselves to be their expertise area were averaged. Questions related to participant professional and educational background were asked in order to ensure that participants had the required knowledge background to be able to answer the study questions. This was done in order to attain background information that might provide additional explanations for participants' answers to the interview questions, especially when providing specific examples (Horwitz & Ferleger, 1980)

3.7.2 Analysis of Data Obtained from the Semi-Structured Interviews

Content analysis is a qualitative data analysis method that "treats the elements of the body of text as empirical entities", "establishes and documents aspects of their characteristics and the relationships between them", and, in turn, "enables investigators to ask and systematically answer research questions about the manner in which the ideas and information contained in that body are conceived or expressed" (Bowen & Bowen, 2008, p. 689). Two types of content analysis approaches were chosen for this study to address the different types of questions that were asked during the interviews. Audio recordings were transcribed using a word processing program (i.e., Microsoft Word) and were analyzed using content analysis, which is typically "used to determine the presence

of certain words, concepts, themes, phrases, characters, or sentences" within interviews (Palmquist, n.d.). The transcribed audio recordings were coded into various categories on word, phrase, and theme levels and examined using both conventional content analysis and direct content analysis approaches (Hsieh & Shannon, 2005).

Conventional content analysis approach was chosen for the interview questions aimed to describe a phenomenon (i.e., technology-induced errors) based on the experiences of study participants. Namely, the researcher used this approach to gather and analyze data from questions that asked the participants to define technology-induced errors, describe the current processes in their organizations aimed at reducing the risk of technology-induced errors, and identify who is responsible for addressing the issue of technology-induced errors (see Appendix D). According to Hsieh and Shannon (2005), "[m]any qualitative methods share this initial approach to study design and analysis" (p. 1279). Based on the methodology described by Hsieh and Shannon (2005), the researcher used open-ended questions and open-ended probes that were specific to the comments of the participants. The researcher analyzed the data by "reading all data repeatedly to achieve immersion and obtain a sense of the whole" (Hsieh & Shannon, 2005, p. 1279). The researcher then read the data word by word to formulate codes and conducted initial analysis by making notes of her first impressions and thoughts. By repeatedly comparing the codes derived and the initial notes and impressions, the researcher identified "labels for codes […] that [were] reflective of more than one key thought" (Hsieh & Shannon, 2005, p. 1279). These labels came "directly from the [data and became] the initial coding scheme" (Hsieh & Shannon, 2005, p. 1279). These codes were then "sorted into

categories based on how different codes [were] related and linked" (Hsieh & Shannon, 2005, p. 1279).

Directed content analysis approach was chosen for those interview questions that were based on prior research, because "[t]he goal of a directed approach to content analysis is to validate or extend conceptually a theoretical framework or theory", and "[e]xisting theory or research can help focus the research question" (Hsieh & Shannon, 2005, p. 1281). Namely, the researcher used this approach to gather and analyze data from questions that asked the participants to comment on the factors that may contribute to the incidence of technology-induced errors (see Appendix D). The list of factors that were used to prompt the study participants was adapted from the research by Borycki et al. (2009a). The same list of factors was used as predetermined codes for analysis. The data were analyzed by reading the transcripts and highlighting all instances that matched those predetermined codes. Those instances that did not fit into a predetermined category were given new codes.

3.8 Rigour

In order to improve validity and reliability of the study, two individuals coded three initial transcripts independently and the differences in coding were discussed and resolved. One of the coders is a domain expert in the area of technology-induced errors. In addition, the following approaches were used to improve validity and reliability of the study (Seale & Silverman, 1997):

- Supporting generalizations by counts of events. This meant that the researcher coded the data and then counted the number of times a particular code emerged in a particular question. These counts were reflected in the study results in

terms of percentages that corresponded to the number of participants mentioning a specific factor, for example, that contributes to technology-induced errors.

- Ensuring representativeness of cases. This meant that specific inclusion and exclusion criteria were used in order to ensure that participants had the required knowledge and background information.
- Objective and comprehensive data recording. This meant that the data were captured using an audio recorder and transcribed verbatim to have the ability to revisit specific discussions after the interviews were done. Notes were also taken during the interviews, but only to note specific items that emerged from participants' answers at the time of the interview in order to ask about these items or ask for clarification during the interviews.

3.9 Original Ethics Approval and Modification

An application for ethics review was submitted to the University of Victoria's Human Research Ethics Board in February of 2011. The ethics approval was received on March 8th, 2011 (Appendix E). The data collection began on March 31st, 2011. The initial ethics application only included the School of Health Information Science alumni mailing list for recruitment. The ethics approval expired on March 7th, 2012, at which time only 12 interviews were conducted. The ethics application was modified to include the School of Health Information Science Graduate Students mailing list and extended for another year to meet the goal of recruiting 15 participants (Appendix F). The last interview (17th) took place in June of 2012.

Chapter 4: Study Findings

This section provides an overview of the interview findings and includes the demographic characteristics of participants as well as their experiences in healthcare organizations with technology-induced errors.

4.1 Demographic Characteristics of the Participants

Seventeen individuals participated in the study, including physicians, nurses, analysts, and managers in various health informatics subfields, such as IT privacy, security, delivery, informatics services, and various combinations of such. 35% (n=6) were female and 65% (n=11) were male. 24% (n=4) were under 35 years old, 41% (n=7) were between 35 and 50, and 35% (n=6) were over 50 years old. The average age of participants was 43.35 years. The average years worked in a clinical or health IT field was 15.31 years, while the average years worked in an expertise area within clinical or health IT field was 12.31 years. Areas of expertise included: medical workload implementation, clinical applications configuration, systems design and implementation, user requirements gathering and translation into configuration, project analysis, training, systems testing and usability, privacy and security analysis, project planning, clinical informatics, oncology, business process improvement, informatics and outcomes, electronic health record implementation, nursing, and decision support.

The table below shows a summary of participants' characteristics.

Table 1. Demographic Characteristics of Study Participants

Characteristic	Frequency
Gender	
Male	11 (65%)
Female	6 (35%)
Age	
Under 35	4 (24%)
35-50	7 (41%)
Over 50	6 (35%)
Years worked in clinical or health IT field	
Under 10	4 (24%)
10-15	5 (29%)
Over 15	7 (41%)
Years worked in an expertise area within clinical or health IT field	
Under 10	5 (29%)
10-15	8 (47%)
Over 15	3 (18%)
Worked with an EHR	16 (94%)

4.2 Technology-Induced Error

Two of the research questions asked if healthcare organizations in Canada are aware of the concept of technology-induced error and if healthcare organizations in Canada know where technology-induced errors come from or what causes them. To determine participant understanding of technology-induced errors, each participant was first asked to define technology-induced error and asked if they were aware of the concept. 76% (n=13) of participants have heard of the term and provided in-depth definitions that are explored in more detail below. 6% (n=1) of participants were not aware of the concept, and 18% (n=3) of participants did not know the term but were aware of the concept/idea (Table 2).

Table 2. Familiarity with Technology-Induced Errors

Familiarity with Technology-Induced Errors	
Heard of Technology-Induced Errors	13 (76%)
Aware of the concept, but never heard of Technology-Induced Errors	3 (18%)
Never Heard of Technology-Induced Errors	1 (6%)

According to Borycki and Kushniruk (2005), technology-induced error is defined as an error that results from using information systems in complex settings and environments in healthcare. In other words, it is an "error that inadvertently occurs as a result of using a technology (e.g., medication errors that result from using a system)", including the use of a CPOE to dispense an incorrect amount of medication or indicate an incorrect medication dose, or to prescribe a medication to which a patient is allergic (Borycki et al., 2009b). When asked to describe the term "technology-induced error", study participants used words such as: "data quality", "data entry error", and "lack of data access".

Participants defined technology-induced errors in differing ways. In general, participants suggested that technology-induced errors can be defined as health IT errors that result from an interplay of issues in systems development life cycle (design, evaluation, implementation, and support), knowledge/training, workflow, human-computer interaction, configuration/compatibility, policy, data access, and content. To illustrate, participant 2 commented on the importance of errors resulting from workarounds due to unreliable data within systems and overreliance on technology:

> "The system, data, you can't access it. People can't rely on it so they have workarounds and stuff. It could be that somebody made a data entry error, so the wrong data are there. People are relying on technology too much, it's so automated that they grab the wrong chart. They don't do the structured balance that you might do for a manual process. That kind of stuff. I don't really see it but I question whether the technology makes the availability of information quicker, so that people's workload increases and they are expected to see more patients in a shorter period of time. Check for balance and expectations around workload."

Participant 5 described technology-induced errors as:

> "a faulty operational decision made by the technology user, facilitated by a flaw in the system's design."

Lastly, participant 17 noted that a technology-induced error results from:

> "[...] inappropriate use as well as inappropriate design of technology."

After the participants were asked to define technology-induced error, they were provided with the definition of technology-induced error (presented at the beginning of this section) and asked to comment on its representativeness. Seven (41%) participants stated that the definition was representative, while nine (53%) suggested that the definition was too narrow. Participants' words suggested that the definition had gaps in the areas of systems development life cycle (including design and implementation), knowledge/training, human-computer interaction, configuration/compatibility, and data access.

More than half of participants regarded the definition provided as too narrow, lacking focus on issues arising from the systems development life cycle (design and implementation), knowledge/training, human-computer interaction, configuration/compatibility, and data access, all of which may actually contribute to technology-induced errors. To illustrate, participant 1 commented on the importance of paying attention not only to technology itself, but also to data interpretation and training:

> "Absolutely, but from my experience, I don't know if it is because of the technology. It could be issue with interpretation of the data, and it could be either lack of knowledge or not aware of what it actually means when you translate it to a business decision. For example, if a system is saying we're not going to allow you to input these data in, so the user might think that the system is not doing something right. In fact, the system is doing the right thing by not allowing you to

> do it. But the user is interpreting it as a technical fault whereas it is actually a business decision preventing from doing so."

Participant 10 commented on the definition of technology-induced error suggesting that technology-induced errors should not be attributed only to technology:

> "Well, it's tricky because when I hear 'technology-induced error', it's more of technology plus the user collaborative error. For example, formatting issue, how something is displayed that makes it more likely to be missed by a user, and then the user is unable to properly make that decision. So I think many of the errors are technology-related, technology-associated rather than technology-induced errors."

To summarise, participants regarded technology-induced errors as very complex errors that result from an interplay of various factors at an individual level (i.e., user interacting with the technology), the system development life cycle level (i.e., all phases from requirements gathering and design to implementation and support), as well as organizational and even governmental levels (i.e., contradicting policies or lack of system-workflow fit). They suggested that there is a lack of awareness of such errors, which, in turn, may be negatively impacting patient safety. Patient safety is discussed in the following section.

4.2.1 Technology-Induced Error and Patient Safety

There was a lack of awareness of technology-induced errors and their possible origins. 24% of participants (n=4) have never heard the term technology-induced error before the researcher provided them with the definition. After the definition of technology-induced error was provided, 100% of participants stated that technology-induced errors either affect patient safety or they have the potential to affect patient safety. When asked to comment on technology-induced error and patient safety, participants used the following words: "overreliance on technology", "lack of business continuity plan", and "clinical

scenario is not widely understood by practitioners involved in the patient care", to illustrate a few.

All participants commented on technology-induced errors' potential to negatively impact patient safety, after the researcher provided the definition of technology-induced error. Participant 1 commented on technology-induced error and its effect on patient safety focusing on what initially might seem as a non-serious situation, but given certain factors presented below, it might negatively impact patient safety:

> "Well, I think it does affect patient safety. For example, just something I came across is, if we can't get the patient in on the right day because of the registration system, while the interpretation from the staff who use the system to register couldn't be exactly what the technology is allowing or not allowing he or she to perform. Therefore, the patient gets scheduled later when that patient was supposed to be at the clinic earlier for her prenatal visit. With prenatal visits, if you miss a visit by a week, that could transfer into very significant clinical indications."

Participant 2 commented on technology-induced error and its impact on patient safety, relating the issue to overreliance on technology and varying degrees of impact based on data or situation in question:

> "Definitely. There can be adverse side effects, anything from fatalities to residual effects. Relying on technology too much. If you have someone's wrong address and you can't get a hold of them (demographics) or someone's wrong birthday. Those things aren't critical. But if a person's allergic to penicillin and it's not entered in the system, that could be fatal. Also, how much the staff rely on the system. But if the system goes down, do they have the contingency plan to ensure continuity? Automation increases the risk, if you don't have a business continuity plan."

Participant 4 commented on varying degrees of impact of technology-induced error on patient safety:

> "Most definitely. It really depends. You could argue that a technology-induced error in radiotherapy could actually kill the patient. A technology-induced error in pharmacy could lead to a serious adverse effect".

In addition, some participants suggested that documentation errors or technology-induced errors that are caught would not have an effect on patient safety. Overall, all participants regarded the effect of technology-induced errors on patient safety as negative or, at least, as having the potential to be negative. They suggested that the negative impact results from interplay of various factors at an individual level (i.e., user's knowledge while interacting with the technology), the system development life cycle level (i.e., design), as well as organizational and even governmental levels (i.e., information passing through provincial systems).

4.3 Qualitative Study Findings

The interview transcripts of participants were analyzed line-by-line and coded for concepts that emerged from the data. These concepts also had overarching themes that emerged from the data. Nine concepts and four themes were identified after the coding was completed. The concepts identified were: systems development life cycle, knowledge/training, workflow, human-computer interaction, configuration/compatibility, policy, data access, user engagement, and content. The systems development life cycle category had five subcategories: requirements gathering, design, evaluation, implementation, and support. The themes identified were: individual, vendor, organization, and government. In this section of the thesis, the researcher describes concepts about technology-induced errors that emerged from the data, including:

- The definition of technology-induced error

- Technology-induced error effect on patient safety
- Technology-induced error causes and factors that contribute to the occurrence of technology-induced errors
- Agents that interplay, interact, and contribute to technology-induced error
- Processes and procedures at participants' organizations to identify, address, report, rectify, and prevent technology-induced errors and what processes and procedures should be in place to prevent such errors
    - Frequency of technology-induced error in different settings
- Responsibility for addressing technology-induced errors.

In the following section of this chapter, the researcher first describes technology-induced errors using the concepts identified in the study. The researcher then explores the nine concepts further, describing each concept in greater detail and relating it to technology-induced errors. In later sections of this chapter, the researcher explores other research questions and topics related to technology-induced error using the nine concepts.

4.3.1 Concepts

In this section, the researcher defines the nine concepts that will be used to present the interview results and relate participants' messages in further sections.

4.3.1.1 Systems Development Life Cycle

The concept of systems development life cycle was captured across 71% (n=12) of participants. The systems development life cycle can be defined as "the overall process for developing information systems from planning and analysis through implementation and maintenance" (UMHS Finance, 2013, p. D2). It "is comprised of seven distinct

phases: planning, analysis, design, development, testing, implementation, and maintenance" (UMHS Finance, 2013, p. D2).

From participants' contributions regarding technology-induced errors and phases in the systems development life cycle where such errors could originate the researcher has deduced that the main phases where technology-induced errors originate are (1) requirements gathering, (2) design, (3) evaluation, (4) implementation, and (5) support. When it comes to technology-induced errors, the systems development life cycle can, therefore, be defined as a process from system inception to its support post implementation, in which all parties affected by the system are involved, including its future users, designers, implementers, and supporters. Participant 16 shared that testing in every systems development life cycle phase is important:

> "I guess it's based on not enough usability testing to ensure that these problems don't come up. So, if the software has not been tested enough with the representative people doing representative tasks, then the chances of technology-induced error are much higher. I'm a firm believer in testing at all levels of the systems development life cycle."

The following sections explore the five phases of systems development life cycle based on participants' feedback and technology-induced errors.

4.3.1.1.1 Requirements Gathering

Requirements gathering is defined as "[t]he process of reviewing business processes to determine the business needs and functional requirements that a system must meet" (TheFreeDictionary, 2013). This definition, however, is missing the involvement of system's future users, which was very strongly voiced by study participants. Participants used the following words to refer to requirements gathering in relation to technology-induced error, to name a few: "no possible way to incorporate all of the right things into

information system content", "lack of system-clinical workflow fit", "user expectation misfit", and "expected functionality". To illustrate, Participant 1 suggested that requirements gathering must be done properly to ensure proper system fit within clinical workflow:

> "If a system doesn't do something it's supposed to be doing, the requirements gathering was not complete, or if it was complete, it was biased. If you implement it and it turns out to be not the way the clinicians wanted it, then maybe the requirements gathering was not completed well enough to factor in the possibility of certain workflow that might arise out of the way they have expected it to be."

Participant 9 revealed that there is no way to know all possible errors or situations where something might go wrong with the system prior to implementing it:

> "[Technology-induced errors occur] all of the time. I'm just saying that because there is no possible way that we have incorporated all of the right things to do in our content within the clinical information system, so even if people are using the content and following it directly, they're creating errors because there's something missing that we didn't know about in terms of the right thing to do."

As a result, requirements gathering in regard to technology-induced error prevention could be defined as the process of capturing end-user requirements, ensuring that those requirements match the business needs of an organization, and translating such requirements into a practical planning and design.

4.3.1.1.2 Design

The design phase of the systems development life cycle is defined as a phase during which "functional, support and training requirements are translated into preliminary and detailed designs" (Klucznik, 2012). System's functional requirements are addressed first through a preliminary system design where functional features are identified, and then through a final system design where technical details are specified (Klucznik, 2012).

Participants commented on the design process extensively, implying that this phase is one of the most important ones. Participants, however, did not comment at all on the actual development phase. In regard to design and technology-induced errors, participants used the following words, to illustrate a few: "lack of data access", "produces workarounds", and "faulty operational decision made by the technology user and facilitated by a flaw in the system's design". Participant 7 commented on the importance of ensuring that the system that is being implemented meets specific standards and design requirements:

> "[…] if you've got garbage in, you're gonna get garbage out. And that garbage out could cause technology-induced errors. It's the responsibility of the vendor to ensure that their product meets certain standards, that they're able to meet the requirements and the design that's required by the client."

Participant 5 suggested that inadequate system design could greatly impact patient safety:

> "[…] if a physician prescribed a drug that was filled by a pharmacy and that harmed the patient, and the family decided to bring a suit to the hospital or the organization, the organization would have to have the capacity to do the investigation and look into the design of the software that was being used and determine if it was potentially the cause of the error."

As a result, the design phase of the systems development life cycle in terms of technology-induced error prevention can be defined as the process where the user and business requirements are translated into a solution that meets both without compromising one or the other.

4.3.1.1.3 Evaluation

The evaluation phase of the systems development life cycle is defined as the process during which "[t]he system is validated through a sequence of unit, integration, performance, system, and acceptance testing" (Klucznik, 2012). The goal of this phase is

to ensure that system functions as expected and that the requirements and expectations of the sponsors are met. “This phase requires strong user participation in order to verify thorough testing of all requirements and to meet all business needs” (Klucznik, 2012). All participants commented on the importance of evaluation, or systems testing at some point in the systems development life cycle. Some participants also expressed the importance of conducting continuous evaluation at multiple stages of the systems development life cycle as well as after the system is implemented and is live. Participants also commented on the importance of continuous evaluation and ensuring that requirements are gathered not only once but on a continuous basis as well. Participants used the following words to refer to evaluation, to illustrate a few: “lack of auditing, checks, and balances”, “lack of usability testing”, and “cover all error possibilities with system testing, user acceptance testing, and integration testing”. Participant 1 said that the impact of system testing and user interface testing on the incidence of technology-induced errors is:

> “[s]ignificant. And that’s actually a security blanket for us, managers. One of the questions that my boss would be asking me is ‘so, if a system is producing an error, how are you guys managing that?’ Testing and user acceptance testing, there’s no way for myself to protect myself from losing my job, as well as to ensure that the patient is safe. And again, I also mention to the people I work with here, during the testing, we’re gonna be comprehensive, we’re gonna do user acceptance testing, integration testing, make a list of all possibilities that could happen even though we have all these factors in place, we have a clear defined process, we have a clear defined functionality, and map it into the business processes. And we try to cover all the possibilities.”

Participant 3 suggested that there is an impact of system testing and user interface testing on the incidence of technology-induced error:

> “[…] if it’s done early and if the user groups are involved, then I think you can catch where there may have been interpretation or development errors that lead to system errors. But I’d noticed that often what happens is user testing or user acceptance testing involves either such a small subset or it involves people that

> aren't truly the users, because the rationale is that, often, the clinicians are too busy and to get their time to just do testing can often be difficult. But if you substitute in people that aren't in the exact same role, they have more time to address it, we find that they don't catch the same errors. They just don't have that familiarity that a natural clinician would have."

Unfortunately, only two participants (12%) suggested that testing should be done early before system implementation, and the rest of the participants talked mostly about user acceptance testing, which is, usually, done at the very final stage before implementation, or even after implementation. User acceptance testing can be defined as "the type of testing where monitored users determine whether a system meets all their requirements, and will support the business for which it was designed" (Dictionary.com, 2003). In addition, only one participant discussed the importance of testing a system a few months post implementation:

> "So, for example, I'll put together an application, which I think is probably functional for most people, and then get people to come in and test it out, and they will almost always find something I hadn't thought of. And then I'll fix that problem, and then I'll get a few more people in there, and review again, and then what we will do is we will roll it out on a trial basis, and, even then, when we roll it out on a trial basis, and then put it into play, I will always do an evaluation about 3-6 months after the actual application's been live to make sure that people have the opportunity to point out flaws and how the system works."

In addition, only one participant stated that even if testing is done properly, there are often times when testing results and recommendations do not get implemented or applied:

> "I think user testing is important. I don't know if we're asking enough people to do the testing and to be part of it, and I don't know if we're listening to the people on the ground. And that's one of my concerns. When I was with my students looking at the training, and the students were making comments, I was like 'how come we are not modifying those and why are we not addressing the comments after?'. So we're not going back on these programs to make sure that we don't go by 'one size fits all', we're not making modifications. I don't know why we are not listening to the user."

Participants' contributions reaffirmed that the area of system evaluation is lacking standards and guidelines that could be used to properly manage and prevent technology-induced errors. While many organizations are aware that system testing should be done, it is clear that doing any kind of testing is simply not enough. There is a need to conduct thorough evaluation of any health information system at all phases of the systems development life cycle. System evaluation in regard to technology-induced error prevention could be defined as the processes of system-user check-ins at various stages of the systems development life cycle on a continuous basis as well as at various stages post implementation.

4.3.1.1.4 Implementation

The implementation phase of the systems development life cycle can be defined as a phase during which "the new or enhanced system is installed in the production environment, users are trained, data are converted (as needed), the system is turned over to the sponsor, and business processes are evaluated" (Klucznik, 2012). The goal of this phase is to "implement, resolve system problems identified during the implementation process, and plan for sustainment" (Klucznik, 2012). Regarding technology-induced errors, some participants suggested that the implementation process is often rushed due to the pressure to meet specific deadlines. Participants expressed concerns that this might often lead to poorly implemented systems, which, in turn, may lead to technology-induced errors. In addition, they talked about ensuring that the system fits the clinical workflow during implementation. Participants used the following words to discuss implementation process and technology-induced errors, to name a few: "usability testing could help", "one size does not fit all when it comes to implementation - continuous

feedback, gradual piloting and implementation, and impact evaluation are needed", and "ensuring the fit to the workflow is crucial during implementation". Participant 14 commented on the importance of allowing system users to test out the system first before using the system in real situations to ensure that nothing was missed as a result of pressing deadlines:

> "'Rush, rush, rush', everybody has to do it. Sometimes the deadline is set by the vendor. It's good if there is time to let whoever is using it to have a go at it, especially to people who are not very knowledgeable in computers, because they are the ones that will find awkward parts and things that don't make sense. And hopefully this gets done while it's still in the design phase."

Participant 16 commented on the importance of understanding the culture and workflow in each organization and setting rather than applying the 'one size fits all' approach:

> "I would say one thing in terms of implementation. We have one area that we do not understand very well – one size fits all. And this comes from my experience when I was talking about the evaluation. The managers would ask this question: we know [tablets] are good, so why are we evaluating this? It seems like there is just no understanding that different organizations have different cultures and needs, and that the implementation process in one organization is going to be definitely different in another organization, depending on their needs, workflows, physicians, other healthcare providers. So I think the implementation process also needs to be looked at from other angles, understanding that continuous feedback and gradual piloting and implementation, and impact evaluation will definitely benefit the identification of any potential technology-induced errors."

Participants' feedback suggested that implementation process is complex and requires customization itself to ensure that the system fits into the clinical workflow and that clinicians are engaged and ready to use the system once it is live. Evaluation in regard to technology-induced error prevention, therefore, could be defined as a process that puts

the clinical workflow fit and user engagement before project deadline to ensure that system is usable and potential for technology-induced error is reduced.

4.3.1.1.5 Support

The support phase of the systems development life cycle can be defined as a phase during which the system becomes operational. “The emphasis during this phase is to ensure that sponsor needs continue to be met and that the system continues to perform according to specifications” (Klucznik, 2012). This is achieved through “routine hardware and software maintenance and upgrades” (Klucznik, 2012). This phase also includes user training and ongoing additional user support (Klucznik, 2012). In terms of support and technology-induced errors, participants mostly commented on the lack of error reporting systems and processes in place specifically aimed at technology-induced errors. To illustrate, participants used the following words: “ensure proper error/incident reporting processes are in place”, “redesign and re-examine the system continuously”, and “appropriate and accurate reporting post implementation”. Participant 3 commented on the importance of encouraging to report and actually properly reporting errors as they occur:

> “[…] Similar with a lot of the incident reporting. It’s very, very difficult to get an organization to report on the incidents that they feel make them look bad. Yet, you know, from the mistakes I have learned, if you don’t report on the incidents or the near misses, one of the health authorities that I worked for, it was a regular quality indicator that they reported incidents and near misses, but to get the nursing and the clinical staff to report something, when, you know, people feel when they fill out an incident report, that you’re pointing a finger at someone who’s done something wrong, so there’s a real stigma there with getting the information so that you can prevent doing something like that.”

Participant 5 commented on the importance of addressing issues raised by actual system users in a timely and standardised fashion:

> "I think everybody has to have big eyes and open minds and big ears so that when the user says I'm having a problem, the IT people don't say, well, you're just resistant to change, which is a very common feedback that the users get. They need to look over the shoulder of the user, they need to see if the system isn't working the way it's supposed to or that the system may be working as the process described six months ago but someone changed the policy unannounced to everybody, and now the process is changed. But the system isn't designed to catch up with the process change. And usually what happens is the vendor says, well, the next build is coming in the new year, no more modifications. In the meantime, things are happening all around it. So, I think, there has to be a much more collaborative effort to ensure that clinical users' voices are listened to in a structured, systematic, and disciplined fashion, and has weight to the policy maker. So the leadership must realize that at some point, as a system becomes useful, and more people use it, your return on time... let me rephrase it. There are groups of cancers, where people don't live very long. But if you look at certain cancers, there's always, what we call, a tail on the curve, meaning there's a small fraction of people who are alive much longer than anyone else for reasons that are often not clear. In my view, if the system is responsive to user feedback and finding of errors that the system promotes or causes or induces, at some times that tail on the curve exists for reporting errors or reporting problems. And then everyone's gonna have to say at some point, ok, when we're getting maybe 5% […] per month of the problem, we'll close the system at that point. But until that happens, the system is open for redesign or re-examination or redesign of the process if the system cannot be modified in a certain way. So, ultimately, what I'm saying is collaboration and structure […] in my mind are the two most important attributes in any kind of healthcare system."

Participants' feedback regarding support and technology-induced errors matched quite well the definition of this systems development life cycle phase provided at the beginning of this section. They emphasised the need to ensure that problems and feedback reported by system users are responded to properly and changes are implemented if needed.

4.3.1.2 Knowledge/Training

The concept of knowledge/training was captured across 88% (n=15) of participants. Knowledge is defined as "facts, information, and skills acquired through experience or education; the theoretical or practical understanding of a subject" or "awareness or familiarity gained by experience of a fact or situation" (Oxford Dictionaries, 2013a).

Training is defined as "the action of teaching a person or animal a particular skill or type of behaviour" (Oxford Dictionaries, 2013b). For the purpose of this study, knowledge and training were used together to code participants' feedback. Knowledge and training were used to refer both to clinical knowledge and training as well as knowledge and training related to clinical information systems. When referring to knowledge/training and technology-induced errors, participants used the following words: "too much reliance on technology", "results from a user's data input due to lack of understanding how to input information correctly", and "lack of awareness when translating system interpretation to a business decision". While most participants talked about knowledge/training in terms of the end user perspective, Participant 1 commented on the importance of knowledge/training of those who design and implement the system:

> "[…] from my experience, I don't know if it is because of the technology. It could be issue with interpretation of the data, and it could be either lack of knowledge or not aware of what it actually means when you translate it to a business decision. For example, if a system is saying 'we're not going to allow you to input these data in', so the user might think that the system is not doing something right. In fact, the system is doing the right thing by not allowing you to do it. But the user is interpreting it as a technical fault whereas it is actually a business decision preventing from doing so."

Participant 2 commented on the importance of continuous knowledge gain and training:

> "Terminology, training, I think, is definitely something that people need to look at. Not just the initial training, but also the refresher training after the first week of implementation. And you have trainers on site. The first month would probably incur huge costs, but at the end it would provide a lot of savings."

Based on participants' feedback, knowledge acquirement and training, in terms of technology-induced errors, is a complex and multi-layered process that includes

acquiring and applying clinical knowledge that enables the technology user to approach the interaction with the system in a critical way. This prevents the user from over-relying on technology in cases where technology may induce an error. It also includes the knowledge and training of those individuals who are responsible for the system throughout its development life cycle.

4.3.1.3 Workflow

The concept of workflow was captured across 65% (n=11) of participants. Workflow is defined as "the sequence of industrial, administrative, or other processes through which a piece of work passes from initiation to completion" (Oxford Dictionaries, 2013c). Most of the discussion of workflow in this study included participants' concern regarding system's fit into the clinical workflow ensuring that the system does not create extra work for its users and does not result in increased number of workarounds. Participants used the following words to refer to workflow: "improper incorporation of workflow", "combination of paper and electronic record (hybrid environment): confusion of a care provider", and "workload". To illustrate, Participant 13 commented on the importance of ensuring that workflow is properly incorporated into systems design and implementation:

> "[…] Then it gets into a lot of the socio-technical aspects. So, just properly incorporating workflow. So a lot of times there's inherent workflow and cultures in the environment that those need to be adjusted to work with the technology. And the mistake is that people sort of throw on the technology without really looking into those aspects, and then that's what actually causes error. But again, the technology itself was doing exactly what it was supposed to do. So, specific to your question, it happens all the time. Less so in organizations that don't use a lot of technology, but if you're in an organization such as ours, which is quite technology-heavy, you could almost find everything on technology, every type of error, everything, on some level, you could link back to technology because much of the workflow and the work of our clinicians are consolidated through technology."

Participant 9 suggested the presence of workflow-related errors:

> "[…] And then there's the work process or workflow errors. You could build a system that has learning mechanisms that sum together vitals, lab information, and nurse observations on patient to create what's called an early warning system. So, if patient is going downhill and needs a very urgent assessment by critical care, you could create those alerts that could do that. We don't have these alerts yet, but it's something, I think, that we could build. If a nurse chooses to collect vital signs at the bedside on a piece of paper and enter them at the end of the shift, that workflow will break the safety that's provided by that type of alert. You could build errors into workflows as well. And one of those is just not identifying the right patient, as I've mentioned before."

Based on participants' feedback, workflow, in terms of technology-induced errors, could be defined as the process that requires properly fitting system integration to ensure that the process of using information technology is seamless and does not produce additional difficulties.

4.3.1.4 Human-Computer Interaction

The concept of human-computer interaction was captured across 65% (n=11) of participants. Human-computer interaction is defined as the field that "attempts to understand and shape the way people interact with computers: the processes they engage in, the resources they use, and the impact they accomplish" (Te'eni, Carey, & Zhang, 2007, p. 1). Study participants used the following words to talk about human-computer interaction and its effect on technology-induced errors: "assess the ergonomics and regular computer use of the users", "inappropriate use of technology", and "tiredness and fatigue, familiarity with the information system". Participant 7 suggested that fatigue and tiredness of system users could greatly impact patient safety:

> "[… technology-induced errors] occur frequently, because you've got humans interacting with information systems, and if we look at the definition that you provided from the medication management perspective, I think you do have errors that happen on a frequent basis. A lot of it is probably more based on human

> factors than it actually is on systems factors. Because, as you can imagine, the more and more patients that you're looking after, you might have fatigue and tiredness that might set in for the practitioners that are using it, also familiarity of the practitioners with using the information systems. You know, you might have a lot of errors that might be low errors that kinda get caught and corrected along the way."

Participant 2 suggested that another area that would help address technology-induced errors is to:

> "[…] look at how big people's monitors are; who are your end-users; what's their eyesight like."

Even though participants did not comment on human-computer interaction extensively, some of their feedback referred to the importance of acknowledging the fact that there are underlying cognitive and ergonomic processes in place when a user interacts with technology. This interaction, if not properly addressed, may lead to technology-induced errors.

4.3.1.5 Configuration/Compatibility

The concept of configuration/compatibility was captured across 47% (n=8) of participants. Configuration is defined as "an arrangement of parts or elements in a particular form, figure, or combination" (Oxford Dictionaries, 2013d), and compatibility refers to "a state in which two things are able to exist or occur together without problems or conflict" (Oxford Dictionaries, 2013e). The concept of configuration/compatibility in this study is similar to the implementation process of the systems development life cycle and workflow, but it mostly refers to the configuration and compatibility of software and hardware as well as different information technology systems within the same organization or those organizations that share information. Participants used the

following words to refer to the concept of configuration/compatibility: “too much automation”, “inability of information systems to interoperate and share data resulting in issues for effective utilization of integrated systems”, and “back-end functions: lack of interoperability when information is being sent from one facility to another”. To illustrate, Participant 12 referred to this issue as:

> “[…] the inability of information systems to talk to one another or to be able to share data, which creates issues and problems for effectively utilizing integrated technology or information system.”

Participant 7 commented on the importance of having information systems that can properly communicate with each other and translate information if the systems are based at different organizations (i.e., interoperability):

> “So thinking of... moving outside of medication management, you might have the technology that provides support within the background of it. So if I’m thinking of integration engines, you might have errors that actually can be induced by the technology. So, say, if you’re looking into interoperability, so information being sent from one facility, and having it be received from another... you know, maybe this is where the technology itself may produce an error based on the fact that it doesn’t understand what’s being sent by the organization. There could be a wrong mapping of information based on some of the human processes that are associated with taking data to another data field, and then having that data mapped in real time. So those are some of the instances of looking at back-end functions.”

For the purpose of this study, configuration/compatibility could be defined as the process of ensuring that system’s hardware and software are working harmoniously, which reduces the risk of technology-induced error, and that systems that share information either within an organization or among different organizations are interoperable and compatible, ensuring seamless flow of information.

4.3.1.6 Policy

The concept of policy was captured across 82% (n=14) of participants. Policy is defined as "a course or principle of action adopted or proposed by an organization or individual" (Oxford Dictionaries, 2013f). When referring to policy, most participants talked about policies local to an organization even though governmental policies were discussed as well. They used the following words to discuss policy and its importance for technology-induced error occurrence: "auditing, checks and balances", "improper incorporation of workflow", and "lack of clear policies and regulations that govern the introduction of technology".

Participant 4 suggested that policy could force the use of technology, which, in turn, might lead to technology-induced errors:

> "Policy could force the use of technology, for example, in solving problem that is not a technology problem and then could create errors. Also policy such as legislation around having access to data in these systems can actually lead to technology-induced errors."

Participant 16 commented on current lack of government policies in terms of mobile technology introduction into healthcare:

> "I believe there are many reasons for [technology-induced error occurrence]: inaccuracies when implementing and deploying technologies in healthcare; also policies and regulations that govern the introduction of technology into healthcare. There's no clear policy about... I'll give you an example. There is no clear policy or standards on mobile devices. All I get is 'we're working on it'."

Given participants' feedback, policy, in terms of technology-induced errors, refers to guidelines, procedures, and ability to customize a system based on local organization's needs (i.e., if the system comes from another organization or if there is a need to share information with another organization). This is similar to Borycki et al. (2009a) research,

where one of the factors contributing to technology-induced errors is identified as a system that is developed for a model organization. According to this research, when a health information system, developed specifically for a particular organization, gets implemented in another organization, technology-induced errors may occur because the system may not fit properly into the workflow and practices of the new organization (Borycki et al., 2009a).

4.3.1.7 Data Access

The concept of data access was captured across 29% (n=5) of participants. Data access is defined as "a user's ability to access or retrieve data stored within a database or other repository. Users who have data access can store, retrieve, move, or manipulate stored data, which can be stored on a wide range of hard drives and external devices" (Techopedia, 2013). In this study, participants referred to data access both from content perspective and system's design perspective. Participants used the following words to discuss data access and its impact on technology-induced errors: "lack of access to required information to enter data", "unintended consequences: dependant on design, timely and appropriate information retrieval", and "lack of quick access to information". Participant 7 talked about access to data both from content perspective and system's design perspective:

> "[…] I think we are at a point where we know our clinicians cannot possibly keep current with all the latest research […]. So, we wanted our clinicians to be much more comfortable so that we're trying to help them and guide them because it's impossible for them to know all this information real time. […] We are trying to bring that information to them at the point of decision-making. And the difference between saying 'go out and get that information' is we want the technology to be so interoperable that it's easily going to retrieve that information, bring it back in a format that's easy for them to understand, and act on to make an informed decision at the point of care. So, we want them to try to avoid the adverse events so that they don't have to fix it at the back end. […] We have to be careful though

> about things that induce errors because the users become fatigued with the way the system interacts with them, because sometimes they will just acknowledge something and go by it. We know that the tendency is to go to the quickest... get the information in the quickest, easy, and usable location, and sometimes that means less scrolling, less clicks, and making it more available to them at that point of decision making, or they will abandon the guidance and move to the wrong decision. […] If it isn't easy to access and doesn't give them the right guidance, you'll find that the CPOE rate of adoption will decrease."

Participant 8 commented on the importance of having access to the right information at the right time:

> "[…] unintended consequences […] are very dependent on that design, pulling that information forward at the right time, at the right place, for the right decision making. And when it's not designed that way, you will get unintended consequences or technology-induced errors."

In order to make informed decisions in terms of providing healthcare and ensuring patient safety, clinicians must have access to appropriate information and that access must be timely. When it comes to technology-induced errors, data access could be defined as an appropriate and timely information attainment in order to ensure proper clinical care, reduce the risk of technology-induced errors, and, as a result, ensure patient safety.

4.3.1.8 User Engagement

The concept of user engagement was captured across 53% (n=9) of participants. User engagement is defined as "a process comprised of four distinct stages: point of engagement, period of sustained engagement, disengagement, and reengagement. Furthermore, the process is characterized by attributes of engagement that pertain to the user, the system, and user-system interaction" (O'Brien & Toms, 2008, p. 938). Participants discussed user engagement as an extremely important factor in the entire

systems development life cycle. They used the following words to discuss the importance of user engagement for technology-induced errors: “clinician engagement throughout system design and implementation”, “user expectation misfit”, and “expected functionality”. Participant 7 discussed the importance of involving clinicians at an early stage of systems development life cycle:

> “[…] requirements have the opportunity to involve the clinicians early on, get them engaged, and get them to elicit requirements, understand their workflow, understand what their current state workflow would be as well as taking a look how that technology could be used in future state workflow with that system in place, would be the means by which you could reduce technology-induced errors.”

Participant 8 commented on the importance of keeping in mind clinical value and clinical benefits when designing, implementing, and redesigning information systems:

> “[…] applying those outcomes to the optimization is another very key part that we tended to under-identify until we realized how powerful that outcomes data was to re-inform the design, because it’s a continuous cycle after that. You use the technology, you measure it, you monitor it, you evaluate it, and then you redesign to get the clinical value and the benefits. The minute the clinical value and the benefits are not at the centre of what you’re doing, you lose your clinician engagement.”

Based on participants’ feedback, user engagement, in terms of technology-induced errors, could be defined as an important strategy in enabling early error detection and increasing user investment to use the system after implementation. Participants suggested that system users must be engaged at all stages of the systems development life cycle in order to capture user requirements at an early stage and ensure that those requirements are incorporated during system design and implementation. User engagement is also crucial during the system evaluation process in order to ensure that user requirements

identified at the beginning of the systems development life cycle and the actual functionality of the system before and after implementation are aligned.

4.3.1.9 Content

The concept of content was captured across 47% (n=8) of participants. Content is defined as "the things that are held or included in something" (Oxford Dictionaries, 2013g). Study participants discussed content mainly from the perspective of duplicate information in the system and lack of access to appropriate information or gaps in content (see examples below). Participants used the following words to discuss content: "error in the information entered into the system", "inadequate, incorrect, or duplicate information", and "content drives care". Participant 8 commented on the opportunity for content gaps due to information being handed off numerous times:

> "At the beginning our eagerness is to get a load of content out there... the clinically complex content... there are a lot of members of the team participating in it, and you hand off that information quite a few times. And there's an opportunity for a gap many times. So we have implemented... if you can't do it for all areas, you certainly can't do it for certain complex areas. And then we have another level what we call clinical testing, where actually we bring in pharmacists, the safety leaders, the quality improvement folks just to get that other pair of eyes beyond the users that kind of challenge the best practice as well. At the end of the day, lots of times, this is what we have to do versus what we would like to do, and we don't wanna design the content on just what has to be done versus what should be done. We want to drive best practice not to supplement less than ideal practice."

Participant 2 commented on the implications of having duplicate information or two sets of different information referring to the same factor within the system:

> "Not having information available when people are used to having it. It could be incorrect information, duplicate systems that don't integrate or integrate poorly, it could be two different sets of information, and one's right and one's wrong, but you can't really see which one is right."

In terms of technology-induced errors, content could be defined as the factor that ties together care, user, and technology. Content drives care and can negatively impact patient safety if it contains errors, duplicate information, or non-useful information. It is the factor that holds together a system, ensuring that the system can be used by clinicians as a tool to provide proper care to patients.

4.3.2 Factors that Contribute to Technology-Induced Error

Participants identified that technology-induced errors may have individual causes as well as result from the interplay of various factors. When asked to identify reason(s) or cause(s) for technology-induced error, participants used the following words: "quality of staff training", "tiredness and fatigue, familiarity with the information system", and "lack of system integration", to illustrate a few. This section explores the factors that contribute to or, potentially, cause technology-induced errors.

88% of participants (n=15) referred to two factors that contribute to technology-induced errors at any point in time. These participants suggested that technology-induced errors arise from interplay of issues in the systems development life cycle (requirements gathering, design, evaluation, implementation, and support), knowledge/training, workflow, human-computer interaction, configuration/compatibility, policy, data access, content, and user engagement. To illustrate, Participant 1 commented on the importance of requirements gathering and the process of configuration:

> "If a system doesn't do something it's supposed to be doing, the requirements gathering was not complete, or if it was complete, it was biased. If you implement it and it turns out to be not the way the clinicians wanted it, then maybe the requirements gathering was not completed well enough to factor in the possibility of certain workflow that might arise out of the way they have expected it to be. But then it could also come from the configuration: certain features weren't turned on and it got missed during testing; maybe the testing wasn't specific enough or not wide enough to catch all the possibilities. I certainly have

> encountered trying to create testing cases trying to capture everything, and encountered that we were biased during our testing. But then again, once it's live, it also becomes part of how well the user is educated and how proficient they are with the system. Because the user could also cause the application to spit out something that it's not supposed to do. For example, maybe he or she selected the wrong unit: instead of 'mg' she selected 'g'. And then the calculation of the dosage might be wrong."

Participant 2 suggested that workload or lack of backup plan in cases when a system is down might contribute to technology-induced errors, among many other reasons:

> "It can be lots of things. It can be workload, if someone's doing a lot of data entry or reading someone's handwriting and entering from that. It could be that the system is down and there are no workarounds, so the people are doing sort of the best guess. Not having information available when people are used to having it. It could be incorrect information, duplicate systems that don't integrate or integrate poorly, it could be two different sets of information, and one's right and one's wrong, but you can't really see which one is right."

Participant 16 commented on only one factor that contributes to technology-induced error (i.e., systems development life cycle – evaluation); however, system evaluation may imply various other factors such as design and system configuration/compatibility, for example, that could contribute to technology-induced errors:

> "I guess it's based on not enough usability testing to ensure that these problems don't come up. So, if the software has not been tested enough with the representative people doing representative tasks, then the chances of technology-induced error are much higher. I'm a firm believer in testing at all levels of the systems development life cycle."

From participants' contributions, it is apparent that the occurrence of technology-induced errors and their sources are complex and multi-dimensional. Such errors, according to the participants, result from interplay of multiple factors at an individual, systems development life cycle, organizational, and governmental levels, as identified previously. The following sections are aimed at exploring these factors in greater detail,

based on the research by Borycki et al. (2009a), where the authors identified a framework for identifying where technology-induced errors come from. The researcher explored ten areas from the research of Borycki et al. (2009a) with the participants, which may cause or have an impact on the incidence of technology-induced errors:

1. Policy at the regional, provincial, or federal level
2. Health legislation
3. Workflow, practices, and terminology that came from the model organization (i.e. the institution the system was initially based on)
4. Terminologies used at the institution the system was based on (e.g. different acronyms for the same procedure depending on organization)
5. Policies and procedures at the local organization
6. User interface design
7. User training
8. Requirements gathering
9. Implementation
10. System testing

These ten areas were presented in detail in the literature review chapter and are explored in greater detail in the following sections. Matching concepts identified previously are included in the following sections as well.

4.3.2.1 Policy at the Regional, Provincial, or Federal Level: Impact on Technology-Induced Errors

The operational responsibility of healthcare spending has devolved from provincial governments (ministries of health) to regional health authorities that have varying

degrees of decision-making authority in most Canadian provinces (Parliament of Canada, 2013). Some regional health authorities have partially elected boards, which "are responsible for local planning, setting priorities, allocating funds, and managing services for better integration and greater effectiveness and efficiency, within provincially defined policy guidelines". The funding is received from the provincial/territorial government (Parliament of Canada, 2013).

When asked if healthcare policy at different levels could impact the incidence of technology-induced errors, 13 participants (77%) agreed that it could, at least indirectly, affect the incidence of technology-induced errors. Participants stated the following to answer the question about policy's impact on technology-induced errors: "decision makers select technology based on policies", "policy can force the use of technology", and "rushed decision making that is not based on user requirements but rather on political pressure". To illustrate further, Participant 5 commented on the interaction among managers in healthcare fields, governments and other healthcare decision makers, and policies:

> "I think policy is a contributing factor, but it more often than not relates to inadequate due diligence and leadership. What I'm getting at is, I think people at very senior levels in healthcare are under significant pressure from politicians and other groups to make things happen in a timely fashion without considering the users requirements and ensuring that the system they pick often on the basis of expediency is inadequately designed for the work that's required. For example, in a province, the ministry decided that they wanted to restrict the number of information systems in use around the province, and decided that we're gonna have just two [...], and it's very unclear to me whether the people at the ministry have inquired people who are gonna use these systems as to their suitability and applicability. So I think the big flaw in policy at the provincial and federal level is that they don't have enough input from people who use the system, and I don't think they take any input seriously. Decisions are being made in the absence of information. [... some] people at the policy level openly admitted, that they don't always paid attention to the evidence because it wasn't always applicable to the kind of decisions they had to make."

Participant 14 provided an example related to electronic prescribing, which shows the discrepancies between government policies and safety of prescribing over the phone:

> "A good example is around electronic prescribing. So, electronic prescribing is not actually legal. Because of that, there are still physicians that will do orders over the phone, which, if you think about it, an electronic message, even if it's sent by email, is more accurate than trying to say complicated medication over the phone. So, because of policy, they aren't able to do those electronic scripts, and so those cause errors. So, at many different levels, because the government primarily sets policy agendas, they have some indirect influence on that, but not really directly, because it's the people who are interacting with the technology and implementing it that have more of that influence."

Some participants suggested that it is actually the process of deployment that affects the incidence of technology-induced errors. They also suggested that policies might encourage something but it may not be feasible as a result of tight deadlines or other pressures, such as budgetary restraints. Participants indicated that policy has the potential to impact the occurrence of technology-induced errors.

4.3.2.2 Health Legislation: Impact on Technology-Induced Errors

"Legislation refers to written laws, often referred to as Acts or statutes, which are enacted by Parliament, the legislative arm of government. Draft legislation, called a bill, is introduced to Parliament and requires the assent of the House of Commons, the Senate and the Crown to become law" (Health Canada, 2006). Health Canada, for example, has established acts related to information access and privacy, which govern the rights of Canadians related to confidentiality of information provided and ability to access required information (Health Canada, 2013).

When asked if health legislation could impact the incidence of technology-induced errors, 82% of participants (n=14) agreed that it could or should affect the incidence of

technology-induced errors. Participants stated the following to answer the question about health legislation's impact on technology-induced errors: "lack of access to information due to poor interpretation or lack of clear-cut legislation around privacy", "possibly when privacy is a concern and roles are not defined properly", and "privacy and confidentiality". To illustrate further, Participant 4 commented on the importance of health legislation in terms of privacy:

> "Definitely, especially around privacy. Interpretation or lack of clear-cut legislation can result in technology-induced errors by preventing people who need to have access to information systems that could lead to lack of access for appropriate people."

Participant 7 commented on the limitations of legislation related to privacy when it comes to sharing necessary information in order for healthcare providers to make informed decisions:

> "I think that the whole privacy issue has gone too far, and because of that it really impedes the ability of systems and programs as a result of safeguarding and securing the patient. So I think sadly enough, the government has enforced to consider privacy and confidentiality, but quite frankly, at the end of the day, with the amount of information floating around, I think they are blowing it way out of proportion, and that there is a very good opportunity to enable more effective sharing of information if we were to relax some of these requirements. I think it's a pigeon hole to the point where we are not doing a good job of sharing information, and that's actually making things worse, not making things better."

In terms of health legislation, most participants focused on the issues of privacy and confidentiality, which may result in lack of data access. Lack of data access may negatively affect health providers' ability to provide proper care, because providers may miss important information such as allergies, past medications, or past procedures. This, in turn, may increase the incidence of technology-induced errors.

4.3.2.3 Workflow, Practices, and Terminology from Model Organization: Impact on Technology-Induced Errors

When asked if workflow, practices, and terminology that come from model organizations could impact the incidence of technology-induced errors, 82% of participants (n=14) agreed that these factors may increase the incidence of technology-induced errors. Participants stated the following to answer the question about workflow, practices, and terminology's impact on technology-induced errors: "yes, but not in a good way due to unique needs of each organization", "yes, terminology and training must be looked at", and "fit in the context of where the application is used". To illustrate further, Participant 5 commented on the importance of analyzing the workflow at a target location:

> "So, typically, importing a model that software was derived from without analyzing the conflict points that occur when you change people's process is an opportunity for errors to occur, the best example being the increase in mortality in a paediatric ICU in eastern U.S. reported about five years ago, where a system was put into play with policies that changed drastically how nurses and physicians and pharmacists worked to look after little sick children who had to go into intensive care [...] it's a good example how a software that was designed somewhere else got into an intensive care unit. Pretty detrimental results based on that observation."

Participant 7 commented on the importance of understanding workflow where the system is being implemented as well:

> "That is absolutely critical. I think anyone who is implementing a clinical information system is going to learn this very quickly. And we do a lot of site visits and often remind them of how workflow and the whole amount of dedicated resources around understanding workflow and best practices and practices in general is often underestimated, under-resourced, and has definite consequences when not being part of your informatics model. We really talk about content enabled by workflow and usability, and driving best practices and improved care and outcomes, so we definitely have great discussions about the power of workflow, if it's working for you or against you if not well understood. A lot of

> our stakeholder working groups when we're doing part of the design and our methodology is around understanding the workflow."

Based on participants' contributions, it is clear that misfit between the information system and the workflow results in technology-induced errors.

4.3.2.4 Terminologies from the Model Organization: Impact on Technology-Induced Errors

When asked if terminologies, specifically, from model organizations where systems were initially based on could impact the incidence of technology-induced errors, 53% of participants (n=9) agreed that this factor could increase the incidence of technology-induced errors. Participants stated the following to answer the question about terminologies' impact on technology-induced errors: "need for consistent terminology, even if it comes from model organization", "jargon", and "cause for confusion". To illustrate further, Participant 6 suggested that information systems may actually help users decode acronyms:

> "Absolutely. We're supposed to minimize the number of acronyms. I mean, EHR might help us. If we're gonna input an acronym, an EHR might translate it into regular English, so there's less ambiguity. So I guess that depends on a system. So, I guess if it can do that, then there would be fewer errors."

Participant 16 suggested that different acronyms or jargon may result in confusion:

> "Yes, for sure. For example, when you're writing out a prescription, there are different ways of how people would say 'give this medication once a day', OD or QD, different ways of writing this out. So it could cause a lot of confusion and have some problems in dosing and stuff like that that we've talked about before."

Based on participants' responses, it is clear that both terminologies and acronyms not only from model organizations for which systems may be built initially, but also from

different departments within a specific organization may have an influence on technology-induced error occurrence.

4.3.2.5 Policies and Procedures at the Local Organization: Impact on Technology-Induced Errors

When asked if policies and procedures at the local organization could impact the incidence of technology-induced errors, 71% of participants (n=12) agreed that this factor could increase the incidence of technology-induced errors. Participants stated the following to answer the question about policies and procedures' impact on technology-induced errors: "'cross-pollination' when clinicians come from facilities that have different local policies and procedures", "risk from local system customization", and "information access restrictions". For example, participant 15 commented on the importance of ensuring that local policies and procedures actually match the workflow of that organization:

> "Absolutely, because those policies would determine how the software is used. And again, if the policies are written by somebody who does not have a good understanding of the workflow and the procedures, then it does certainly have an impact. For example, if it says that you have to use these order sets, and there is something that doesn't work properly within the order sets... policy has to be sensible, because it could increase the workload."

Participant 17 provided an example of varying degrees of information access by healthcare providers, which may interfere with proper care:

> "Yea, oh, for sure. A great example would be transitioning patients in and out of hospital. Who has access to which record depends on who they're employed by not what they need to see or by local policy around access control. A good example would be a nurse in a nursing home [...] is only allowed to see patients who are admitted to his or her ward, but they transfer patients from the hospital to the nursing home almost daily. They're not allowed to see the patients in the hospital until they've been transferred down. So they can't actually plan their care until they've seen that record, and that only occurs when the patient is physically

> on the ward, so they can't pre-plan. Access policy – easily fixed – one button. I mean, literally, it's a tick box, and yet the local policy is that nurses shouldn't need to see anybody else. And they haven't changed that in 10 years. And any nurse you talk to in the long term care will complain about how difficult that is."

Based on participants' contributions, it is clear that policy not only at the governmental level, but locally as well, has a great impact on the incidence of technology-induced errors. Local policies can negatively impact data access and workflow, which, in turn, may result in technology-induced errors.

4.3.2.6 User Interface Design: Impact on Technology-Induced Errors

When asked if user interface design could impact the incidence of technology-induced errors, 94% of participants (n=16) agreed that user interface problems could negatively affect the incidence of technology-induced errors. Participants described their thoughts regarding user interface design in the following manner: "intended use vs. actual use", "default settings and lack of notification for the need to redo some actions", and "one size does not fit all; garbage in garbage out and lack of proper safeguards to monitor and audit the work". To outline how participants felt about the problem, Participant 3 commented on situations where healthcare providers did not trust the data that they received, and how this resulted in reordered tests, duplicate data, and additional costs:

> "Things with user interface problems, specifically, working with EMRs and the provincial lab systems... the recognition that... when the care providers do not trust the data they're getting, that's when they reorder tests for themselves. So their way to prevent having a potential error is to retest, so that they have the data themselves at an additional cost to the healthcare system. Between referring physician, between GP and the specialist, and within hospital, if they're getting results from the interior hospital to tertiary facility, if the doctors feel that the lab tests have not been done the same way or if they don't trust the results are complete or if they don't trust anything about it, when it's critical in nature, they just reorder... it's easier for them to just reorder. And they don't think about cost."

Participant 7 talked about the importance of displaying clinical information in a meaningful way:

> "So if users are not familiar with the user interface that they're looking at, they don't understand the terminology that might be used, it might not be necessarily that intuitive, you might have a button that is not clear, so I think user interface probably has a lot to do with it. If I can't find what I'm looking for, and I need to look around, I might overlook something that I don't necessarily can see. If I'm looking at clinical information that's presented to me, either a report or laboratory information, and it's not provided in a way where I can meaningfully pull up the information that I'm looking for, then of course it's got opportunity for technology-induced error."

While user interface design issues may cause the greatest challenges when it comes to technology-induced errors, proper user interface design needs to go hand in hand with proper user training.

4.3.2.7 User Training: Impact on Technology-Induced Errors

When asked if user training could impact the incidence of technology-induced errors, 88% of participants (n=15) agreed that poor user training could lead to increased incidence of technology-induced errors. Participants used the following words to describe their thoughts: "lack of long term training strategy and presence of bad habits being transferred by old users to new users", "lack of training leads to wrong assumptions", and "non-effective training that is deployment-oriented". To illustrate further, Participant 3 commented on the importance of continuous user training rather than training users only at the beginning when a system is implemented:

> "Yes, I think that's key. I think things that are often not addressed are when, you know, a lot of user training is done at the beginning, and then there's a lot of turnover with staff or new staff that joins, and there might not be a long term strategy on how to have everyone informed and if you don't have a structure in place, you have bad habits. Some healthcare places or hospitals might have the vendor in only to do the initial training or super-user training, and then the organization often takes over how they will continue to maintain their staff having

> a certain level of training. But, you know, especially if you have a nurse joined and the next training-orientation type event is not for another month, you're gonna have a co-worker show them quickly how to do things. And that's where there might be openings for error, because they're not really getting proper training, they're getting a quick lesson. There could never be, with how we use casual workers and new people coming in, you could never have fully oriented in a system prior to them starting. Usually, when they start, there is the expectation that they would have to use the system at some point."

Participant 7 outlined the importance of actually applying the skills and knowledge obtained during training to ensure that the users actually understand and are able to properly use information systems:

> "Many experiences have been that we did the training and 100% people were trained, but they haven't actually really applied the knowledge. The first initial part of the knowledge is the awareness and the kind of... seeing it and looking at it many times, and participating in working groups, but the actual, what we call summits of practice of doing it more than seeing it, and observing it, and watching it, and thinking that you've passed the test in terms of learning, and then applying that knowledge... the practical application, and then going back and seeing the consequences of not understanding why we stressed certain workflows is probably the most important part of what we typically would previously call training."

Most participants alluded to lack of proper training, and, moreover, lack of continuous training as being a major issue that contributes to technology-induced errors. Participants suggested that user training should not be a one-time occurrence, and that in order to have users use the systems properly, they should be trained and tested on a continuous basis.

4.3.2.8 Requirements Gathering: Impact on Technology-Induced Errors

When asked if requirements gathering could impact the incidence of technology-induced errors, 94% of participants (n=16) agreed that a lack of process of requirements gathering or improper process of requirements gathering could lead to increased incidence of technology-induced errors. Participants used the following words to describe

their thoughts: “usability testing with front line people to identify areas to enhance”, “understanding business requirements is challenging and when done improperly may result in systems functioning not the way they were intended”, and “improper requirements gathering may not address subtle workflow issues”. To illustrate this further, Participant 12 commented on the disconnect between the clinical and the technical sides of requirements gathering and implementation:

> “We call it the structural programming or master planning. We’re doing needs analysis. Again, sometimes I question the capacity of the people that are actually managing those programs. Do they actually understand what it is they’re trying to do? On the other hand, the clinical folks might not have the understanding about any of these programs, and they’re so busy and swamped to engage. So I don’t think that when you talk about requirements or program planning there’s a clear understanding of what it is that they want to accomplish. So, is the technology driving the program or is it the clinical side that’s driving the program? I think sadly enough there is a gap between the two, which is magnifying this issue as well. The clinical people probably know what they want, and a lot of times the technical people are under-resourced as well, and they haven’t spent enough time working with the clinical folks. The other thing is that [some] vendors [...] are all highly motivated and interested in promoting their own systems, but sadly enough that’s gotten a lot of health authorities in trouble too, because a lot of times they don’t realise that those systems are proprietary and they don’t talk to the other systems, and that potentially causes a lot of frustrations.”

Participant 17 commented on ensuring that proper requirements are documented during the requirements gathering process:

> “Invariably, it involves long lists of features that are not in context. And it’s the context that, I think, is very important. I’m a strong believer that the visual context is a big part of some of these requirements, and we miss that - the workflow and the visual context [, which means that the individuals from whom the requirements are gathered have a visual representation of the features that they require the system to be capable of]. We are so used to, in the technology procurement field, to ‘here’s the list of 600 requirements – tick off the ones that you need’, and then the person who has ticked off the most boxes wins.”

In regard to requirements gathering, most participants identified that the communication and the understanding of gaps between clinical and technical professionals required more effort. These gaps, as suggested by the participants, may lead to miscommunication, which, in turn, may lead to systems that are unusable or that do not fit well into the workflow, and this may result in technology-induced errors.

4.3.2.9 System Implementation: Impact on Technology-Induced Errors

When asked if system implementation could impact the incidence of technology-induced errors, 82% of participants (n=14) agreed that issues with the implementation process could lead to increased incidence of technology-induced errors. Participants used the following words to illustrate a few of these instances: "implemented system in real environment may result in processes that are different from intended processes", "ensuring the fit of user requirements and user training", and "improper or rushed implementation, improper customization, improper review of user requirements documentation, lack of internal check process to validate that the system functions meet the requirements". Participant 4 commented on the importance of ensuring that clinical workflow is well understood before implementing a system:

> "[...] the implementation of a CPOE in a paediatric hospital, where it basically said to give a patient a med, they had to be entered into the system, and I think there were a couple of cases where paediatric patients actually died because they needed emergent care, but nobody could open the med cart to give them meds because the patient wasn't in the system. They had to be entered, and there was no workaround to get them into the system."

Participant 7 suggested that there are many different factors that contribute to technology-induced error prior to implementation:

> "Yes, if it's not implemented properly, if it's rushed, if you've got the wrong people that are involved with it, if it's not customized properly, so that

> requirements documentation isn't reviewed appropriately, haven't gone through the internal check process to validate that these functions do make sense based on requirements, and the overall architecture of the solution based on the way that these different components work with each other... then you will have opportunities for technology-induced errors."

According to the participants, the process of system implementation is just as important as the actions undertaken prior to system implementation in order to reduce the potential of a technology-induced error occurring. System implementation is a step that must be taken between requirements gathering and design, and user training and support.

4.3.2.10 System Testing and User Interface Testing: Impact on Technology-Induced Errors

When asked if testing could impact the incidence of technology-induced errors, 82% of participants (n=14) agreed that improper testing or lack of testing could lead to increased incidence of technology-induced errors. Participants used the following words to describe their thoughts: "cover all error possibilities with system testing, user acceptance testing, and integration testing", "ensuring that an adequate and representative user group is involved in testing", and "continual development through repeated system testing with users" is conducted. To illustrate this further, Participant 3 suggested that it is important to test with a larger population of real system users to ensure that possible errors are caught early in the process and patient safety is not impaired:

> "Yea, if it's done early and if the user groups are involved, then I think you can catch where there may have been interpretation or development errors that lead to system errors. But I'd noticed that often what happens is user testing or user acceptance testing involves either such a small subset or it involves people that aren't truly the users, because the rationale is that, often, the clinicians are too busy and to get their time to just do testing can often be difficult. But if you substitute with people that aren't in the exact same role, they have more time to address it, we find that they don't catch the same errors. They just don't have that familiarity that a natural clinician would have."

Participant 7 noted that early testing should be done not only to ensure that there are no critical errors present, but also to determine whether a system is actually capable of actions that it is supposed to be capable of:

> "I would say yes. So, having users involved, so I guess looking at user acceptance testing. It would have an impact, because you have the opportunity to have users preview some of the functionality in the prototype, so that you can actually identify some of those high, medium, and low level types of errors that might come up and have the means that you can plan to actually address that. The interface side of things... you absolutely need to do the testing because you need to make sure that the information from one system can actually A) be transmitted, and B) be received by the other information system. So yes, I would say both of those have possibilities for reducing technology-induced error."

According to the participants, testing with actual users is a good process for uncovering errors that may impede patient safety or result in usage difficulties. Both system testing and user interface testing are important in the prevention of technology-induced errors.

4.3.3 Processes and Procedures in Canadian Healthcare Organizations

Given the complexity of technology-induced error causality and occurrence, the researcher documented participants' suggestions about what could or should be done to reduce and prevent technology-induced errors.

Participants suggested that there were seven areas, where the management of strategies could be applied to address technology-induced errors, namely the systems development life cycle (including requirements gathering, design, evaluation, implementation, and support), knowledge/training, workflow, human-computer interaction, configuration/compatibility, policy, and user engagement, but NOT data access and content.

Even though the participants identified data access and content as factors that contribute to technology-induced error occurrence, none of the participants were able to identify solutions data access and content issues. Most participants focused on the systems development life cycle phases and knowledge/training as the main areas where factors that contribute to technology-induced errors could be addressed. To illustrate this further, Participant 1 talked about "substantial time spent on requirements gathering":

> "The question I ask myself as a manager is: is the system going to be actually manned by the person who leads the user requirements gathering? Did the vendor mistell me something? Is the nature of the system fully identified to us during the sale process? Did we do a good job during the process to learn everything from the vendor? I wonder if we did a good job to understand the system fully? Or the vendor itself? So I think that's one area that I would have my team spend more time on. So that we don't have the exchange such as 'you didn't tell us – you didn't ask'."

Participant 3 commented on user training and proper support through appropriate reporting mechanisms:

> "Well, I guess there's the two main aspects to trying to reduce it. On the user side, the training process or the method in which you keep everyone up to date so that they don't create the errors, and also how the reporting of the errors is done. Similar with a lot of the incident reporting. It's very, very difficult to get an organization to report on the incidents that they feel make them look bad. Yet, you know, from the mistakes I have learned, if you don't report on the incidents or the near misses, one of the health authorities that I worked for, it was a regular quality indicator that they reported incidents and near misses, but to get the nursing and the clinical staff to report something, when, you know, people feel when they fill out an incident report, that you're pointing a finger at someone who's done something wrong, so there's a real stigma there with getting the information so that you can prevent doing something like that."

Overall, the participants were able to describe how technology-induced errors could be reduced or prevented. Each participant focused on a specific area, however, and did not talk about all of the factors as a whole that could prevent technology-induced errors.

While some participants felt strongly about addressing potential causes of technology-induced errors in systems development life cycle processes, others focused on improving training/education as a preventative strategy so that individuals would be more aware of technology-induced errors.

4.3.4 Current Practices for Reducing the Risk of Technology-Induced Error and Responsibility for Addressing Technology-Induced Errors

Participants were asked to estimate how often they thought technology-induced errors occurred at a typical hospital or health authority (based on their experiences). Even though technology-induced error reporting was not supported at the time of the study within most organizations where the participants worked, “common”, “frequent”, “daily”, “hourly”, and “all the time” were the words participants used to describe the frequency of technology-induced error occurrence. Given such high-perceived frequency of technology-induced errors, participants were asked if their organizations have any processes in place for reducing or preventing technology-induced errors. In response to the question, participants used the following words: “quality assurance”, “user acceptance testing as part of the implementation process”, and “change management strategy”, to illustrate a few. This section explores participants’ feedback regarding the processes in place at their organizations that were directed towards reducing or preventing technology-induced errors.

18% of participants (n=3) stated that there were no processes in place at the time of the study to reduce and prevent technology-induced errors in their organizations. Other participants talked about current processes in place that could, potentially, aid in reduction and prevention of technology-induced errors, but none of the processes

described were aimed, specifically, at technology-induced error reduction and prevention. Participants' words suggested that there were six overarching concepts, where the discussion of strategies implemented at participants' organization to address technology-induced errors were present: systems development life cycle (including requirements gathering, design, evaluation, implementation, and support), knowledge/training, workflow, policy, content, and user engagement, but NOT data access, configuration/compatibility, and human-computer interaction.

Participants mostly talked about the systems development life cycle process and training when asked about the processes and procedures in place at their organizations that might reduce or prevent technology-induced errors. Again, it should be noted that these processes identified were not specific to technology-induced errors. Participant 1 suggested having proper mechanisms in place to ensure high data quality, especially when the information is being transferred from another institution where, perhaps, the quality of the data may not be as high:

> "We have extensive amount of work around data quality and duplicate checking and testing. And that's in terms of receiving data, so I'm speaking more in terms of information management. We have to do a data quality check to ensure that... we couldn't trust what our hospital clients would submit to us, because their system allowed them to input data incorrectly. Either because certain systems had the right to override the clinical manager or they just entered incorrect data and the system never caught it."

Participant 14 listed a number of factors that could aid in reducing the risk of technology-induced errors:

> "Having people work together really closely, being aware of how the software is being used, what the workflows are, and being able to find out from users what the problems are, quality monitoring, evaluation of some of the outcomes, and really taking your time for implementing the system, doing the change properly, getting the end user involved very early, find out what product they are using

> now, what's working for them now, what's not working for them now, and just having this communication going on all the time throughout the whole systems development life cycle."

Given that the participants commented extensively on data access, configuration/compatibility, and human-computer interaction, it was interesting to find that none of these three concepts were present when asked about processes and procedures in place at participants' organizations to reduce and prevent technology-induced errors. As a result, it is apparent that there is a real lack of standardized procedures that would help organizations to address this issue. Given this result, it is imperative to explore the responsibility of addressing technology-induced errors.

4.3.4.1 Responsibility to Address and Prevent Technology-Induced Errors

When asked whose responsibility it should be to address this issue, 88% of participants (n=15) suggested that the responsibility should be "shared". To illustrate, Participant 1 suggested that both the decision makers and the staff on the front line are responsible for addressing and preventing technology-induced errors, be it through system implementation strategies or reporting of errors:

> "I think local policies and local decision makers carry a lot of responsibilities in terms of operations, and I think they need to appreciate the fact that if technology can be enabled in a way to reduce errors, then they definitely need to look into it. But then they need to make a case to the people they report to. So it's a shared responsibility. And on the vendor side, if there was something I had a problem with, and the vendor says 'This is not our area of focus', this has become a feature that us, the consumers, need to look into. So the people in decision making process need to understand what they are getting themselves into with the vendor, if the vendor is not going to pay attention to these things, then it's not worth the contract, even if they have one outstanding feature on the market."

Similarly, Participant 9 commented on the importance of having ongoing communication and interaction among those involved in using the system and providing care:

> "Well, like everything else in healthcare, everyone who interacts. Particularly, people who build, configure, and deploy the technology to the clinical work area."

On the contrary, some participants implied that there should be only one person or a single group, who should take on the responsibility for addressing technology-induced errors. For example, Participant 5 commented:

> "I would assume each organization should have a CIO, and they would ultimately be responsible."

Similarly, Participant 4 suggested that the responsibility should be embedded in the organization's policy:

> "I think it should be embedded in the organization's policy. Like, for us, we have a whole patient safety group. And I think that's their responsibility."

Based on participants' contributions, it is safe to conclude that the responsibility for addressing technology-induced errors should be shared. Participants suggested that effective communication is a part of sharing responsibility.

4.3.5 Themes

From participants' contributions it is clear that there are numerous underlying interactions that may contribute to technology-induced errors. For example, if an individual is not properly trained, either from a clinical perspective or the perspective of using an information system, it is both the responsibility of the individual and the organization where the system is implemented. To clarify, the individual is not

responsible for improper training, but the individual is responsible for using critical thinking when interacting with the system and avoiding overreliance on technology. The organization, on the other hand, is responsible for providing proper training and support to system users at all stages of user-system interaction, not just at the beginning when the system is implemented. Similarly, the vendor is responsible for meeting design requirements of the organization, but the organization is responsible for clear communication of those requirements to the vendor and for ensuring proper and clear documentation outlining all official requirements to the vendor.

4.4 Summary

To summarize the findings based on the contributions of the research participants, as presented earlier, technology-induced errors can be described as a new class of error arising from the use of health information systems. Technology-induced errors may also be referred to as faulty operational decisions made by technology user and facilitated by a flaw in the system's design. According to the participants, technology-induced errors are a continuously increasing issue that causes risk to patients or other areas of patient care. Technology-induced errors are embedded in the application of technology. The research participants concluded that technology-induced errors may result from technology itself due to incorrect coding, a lack of data access, a lack of structured balance checks, a lack of access to required information to enter data, too much automation and overreliance on technology, increased workloads due to increased information availability, user's data input due to a lack of understanding how to input information correctly or due to proper information display by the system, redundant or frustrating system design, poor system

usability such as the way that the system requires the user to enter information or improper screen display and layout, and content errors.

Nine concepts were identified in this study that act as factors that contribute to technology-induced errors: systems development life cycle, knowledge/training, workflow, human-computer interaction, configuration/compatibility, policy, data access, user engagement, and content. These concepts were defined from the perspective of technology-induced errors. In addition, four overarching themes were identified: individual, vendor, organization, and government. The following chapter is a discussion of the study results and their relation to current literature as well as gaps identified in the literature and the study results.

Chapter 5: Discussion and Conclusion

1.1 Introduction

The goal of this chapter is to discuss the study findings in the context of the current research and answer the following questions:

1. Are healthcare organizations in Canada aware of the concept of technology-induced error?
2. Do healthcare organizations in Canada know where technology-induced errors come from or what causes them?
3. What factors contribute to the incidence of technology-induced errors?
4. Do healthcare organizations in Canada have specific processes and procedures in place to identify, address, report, rectify, and prevent technology-induced errors?
5. Who is responsible for addressing this issue?

5.2 Technology-Induced Error Awareness in Canadian Healthcare Organizations

As identified in the literature review, information about technology-induced errors in healthcare is lacking, which prevents the development and application of proper health IT risk management approaches. In order to achieve this, the problem of technology-induced errors must be first defined properly, and such a definition can only be made possible if healthcare professionals and organizations are aware of these errors. From the results of this study, it is clear that while many individuals have heard of the concept of technology-induced error or have encountered such errors in their practice, the actual definition of technology-induced error is not widely agreed upon. While most individuals

participating in the study suggested that technology-induced errors are caused by interplay of various factors, there was no consensus on the exact factors that cause these errors. The fact that most participants in the study had background in health informatics shows that this might be an educational issue, which contributes to the current awareness level of technology-induced errors. This corresponds to the literature reviewed, which identifies a lack of awareness of technology-induced error occurrence (Borycki & Kushniruk, 2008; Kushniruk et al., 2005) and a lack of acceptable definitions of information technology errors in healthcare (Sittig & Singh, 2011). Many of the studies described in the literature review were aimed at identifying various types of unintended consequences (Ash et al., 2007) and describing how technology-induced errors arise from poorly designed technology or interactions with the technology (Ammenwerth & Shaw, 2005; Brown et al., 2008; Horsky et al., 2005; Borycki & Kushniruk, 2005; Koppel et al., 2005; Kushniruk et al., 2004). In addition, based on the study results, none of the participants were able to give any statistically based numbers on the frequency of technology-induced error occurrence at their organizations. This shows that there is a lack of reporting mechanisms in place for monitoring the frequency of such errors, which, in turn, impedes not only the level of awareness of these issues but the ability to address and prevent these errors as well. This is congruent with the results found in the literature, which show that there might be limited reporting of technology-induced errors in Canada. There is a need to further develop reporting mechanisms and systems in healthcare settings for reporting such errors (Kushniruk et al., 2013).

5.3 Causes of Technology-Induced Errors

The researcher found that most participants could identify some possible causes of technology-induced errors. The difference between the information gathered from the study participants and the literature reviewed is that none of the participants talked about all five areas of technology-induced errors: individual, governmental organization, model organization, vendor organization, and local organization (Borycki et al., 2009a; Orlinkowski, 1992). In addition, there were no overlapping answers among the participants that would suggest a clear cause or causes for technology-induced errors in healthcare environments. This shows that there is an evident lack of awareness of technology-induced errors and their occurrence, as stated previously, and a lack of understanding of what exactly causes technology-induced errors and how this issue should be solved by those who work with health information systems in Canada. This may also be a result of a lack of attention being paid to technology-induced errors in health informatics education, medical education, and related disciplines. This shows that there is a need to include information about technology-induced errors in these curricula.

5.4 Factors that Contribute to the Incidence of Technology-Induced Errors

The majority of participants identified at least two factors each that may contribute to technology-induced error at any time. This shows that technology-induced error occurrence is a complex issue and solving such an issue requires complex actions as well. None of the participants listed all factors presented in the literature that may contribute to the incidence of technology-induced errors. This is not consistent with the information presented in the literature reviewed. The literature provides an extensive list of factors that contribute to technology-induced error incidence (Borycki et al., 2009a). As stated

previously, this might also be a result of technology-induced errors not being extensively studied in health informatics discipline.

Figure 1 illustrates the nine concepts identified in the study that act as factors that may contribute to technology-induced errors: systems development life cycle, knowledge/training, workflow, human-computer interaction, configuration/compatibility, policy, data access, user engagement, and content. The four overarching themes (or layers) are also displayed in the figure showing how these factors overlap: individual, vendor, organization, and government layers. These themes suggest that there are multidimensional layers or agents that contribute to technology-induced errors in addition to the nine concepts presented. Compared to the literature, some of the factors discovered in this study did match those published in the literature, such as policy, workflow, user training, requirements gathering, implementation, testing, and human-computer interaction. There have been additional factors identified in the study that are not reflected in the current literature: user engagement, content, data access, configuration/compatibility, and the importance of the entire systems development life cycle rather than single components of it.

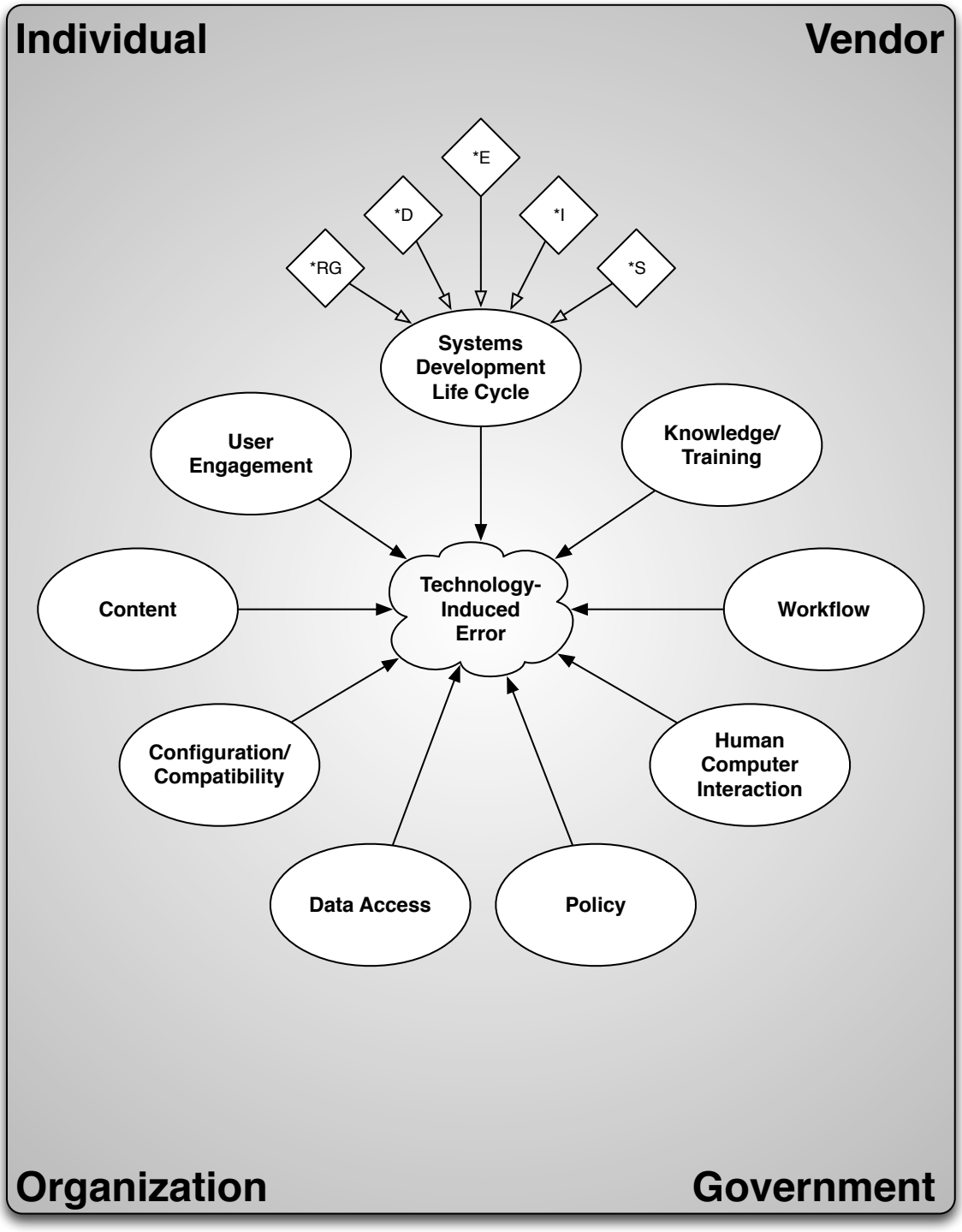

Figure 1. Factors that Contribute to Technology-Induced Errors

*** RG = Requirements Gathering, D = Design, E = Evaluation, I = Implementation, S = Support**

5.5 Current Processes and Procedures for Managing Technology-Induced Errors

As described in the findings section, none of the participants alluded to having or knowing of processes or procedures at their healthcare organizations for, specifically, identifying, addressing, or preventing technology-induced errors. While some organizations have certain processes in place, such as training and paying close attention to systems development life cycle phases, there are no clear-cut, policy-like procedures in place for, first, reporting technology-induced errors, and, second, addressing these issues when they arise, or, third, preventing such errors from happening in the first place. In comparison to the study findings, the findings in the literature show that at the time these data were collected there were no established reporting mechanisms in place in Canada for reporting these errors. Similarly to the study by Borycki and Keay (2010), where the researchers identified a lack of such error reporting systems both nationally and regionally, this study revealed that there were no error reporting procedures in place aimed specifically at reporting technology-induced errors at those healthcare organizations where the study participants worked. There are, however, some reporting systems in place in the United States, pioneered by the Food and Drug Administration (Magrabi et al., 2012; Myers et al., 2011) that allow for reporting of health IT related errors, but these systems are not specific to technology-induced errors.

5.6 Responsibility for Addressing Technology-Induced Errors

Most of the participants suggested that the responsibility for addressing technology-induced errors should be shared: it is the responsibility of healthcare decision makers and leaders to ensure that the information technology implemented in healthcare settings

meets the needs of frontline healthcare professionals, and it is the responsibility of the healthcare professionals to bring the attention of those decision makers and leaders to such issues when they arise. This can be achieved through ongoing and open communication and by ensuring that frontline healthcare professionals would not be blamed for errors that arise due to inadequate systems or misfit between technology and workflow as a result of inadequate requirements gathering or systems testing. While the literature is unclear as to who should take the responsibility for addressing technology-induced errors, risk management should be incorporated into health IT management and should include the management of technology-induced errors. In other words, while there are no clear guidelines in the literature as to assigning responsibility for technology-induced errors, some literature suggests that the responsibility should be collaborative (Kushniruk et al., 2013), as has also been found in this study.

5.7 Contributions to Health Informatics Practice

The author believes that the results of this study may aid in bringing greater awareness to the issue of technology-induced errors, which, in turn, would help develop mechanisms and procedures for reporting, addressing, and, finally, preventing technology-induced errors in the future. This would have a great impact on patient safety, ensuring that the health IT that is being implemented does not impede patient safety, but serves its intended purpose: providing the best access to necessary patient information in order to aid in informed decision making by healthcare providers. This, in turn, will increase patient safety and ensure best possible care for patients. As a result of this study, health informatics practitioners may be made aware of the current situation in various Canadian healthcare organizations related to technology-induced errors and their

awareness of technology-induced errors. As it has already been established in the findings, the awareness is currently low. This could drive the need for health informatics specialists to pay closer attention to technology-induced error occurrence in their organizations, and, as a result, develop practical solutions for addressing technology-induced errors together with their management teams. In other words, the findings from this study could enable various decision makers and stakeholders to get involved in developing strategies to expand the awareness of technology-induced errors, managing these errors, as well as preventing them in the long run. Specific factors identified in this study that contribute to the incidence of technology-induced errors may act as a blueprint for creating guidelines and implementing procedures in healthcare organizations to inform those involved about the severity of these errors as well as report, address, eliminate, and prevent such errors.

5.8 Contributions to Health Informatics Education

It is crucial to bring greater awareness of this issue to students and health informatics academia, ensuring that new professionals are aware of the issue and are better equipped with the necessary skills to tackle the issue of technology-induced errors. The results of this study showed that even health informatics professionals are not fully aware of technology-induced errors. As mentioned earlier, this might be the result of a lack of importance being placed on technology-induced errors in health informatics education. Similarly, in terms of contributions to health informatics practice, the author hopes that the results of the study can act as a blueprint for identifying current gaps in the health informatics curriculum. The results of this study could also aid in implementing changes that would enable health informatics students to be more aware not only of these errors as

such but to also have tools that would help these students to identify factors that contribute to and cause such errors in their future healthcare organizations. The author also hopes that the findings of this study will aid these students to develop the tools to address technology-induced errors and prevent these errors from occurring.

5.9 Future Research Directions

Since technology-induced error awareness and the understanding of what exactly causes technology-induced errors are currently fairly low, there is an evident lack of reporting mechanisms in place to address this issue. Future research should be focused on implementing and closely monitoring the effect of reporting systems aimed specifically at technology-induced error reporting as well as the impact on patient safety of such systems. A direction to take could be the design and development of a reporting system aimed at technology-induced errors and its pilot testing at a local organization in order to obtain data on the types of errors reported and its influence on the awareness and numbers of technology-induced errors. In addition to this, more research resources should be allocated towards applying measures related to the concepts and themes identified in this study to ensure that the list is extensive and exhaustive enough and that no other factors are present that may contribute to technology-induced errors. This type of research could be undertaken after a successful reporting system is put in place and deemed functional (i.e., post pilot testing). Based on the data gathered from the reporting system, comparisons could be made between the current list of factors available in the literature, the factors identified in this study, and the factors that arise when actual technology-induced errors are reported. The next step would be to develop comprehensive and extensive health IT risk management guidelines and procedures to

ensure that standardized approaches are taken when introducing IT systems into healthcare environments. Finally, and most importantly, there is a need to introduce technology-induced errors and patient safety into health informatics and medical curricula as a separate course. This would lead to a greater awareness of the topic and tools required to manage technology-induced errors in a workplace and, in turn, improve patient safety.

5.10 Study Limitations

One of the main limitations of this study was participant self-selection to participate in the interviews. This meant that mostly only those participants who were at least somewhat aware of the concept of technology-induced errors chose to participate in the study. In addition, even though there was a discussion around organizational policies and their relation to technology-induced error, there was no ethics approval to actually obtain such policies from the participants, and, in turn, compare them. These policies, therefore, are not represented in the study findings. In addition, while the sample size for the study was appropriate for identifying key concepts and themes, representation across Canada and different disciplines might be limited. The number of study participants could not, possibly, represent all Canadian healthcare organizations completely; however, as a result of the real life examples provided by the study participants as well as the concepts and themes that emerged from the data, the transferability of the results can be considered high. In other words, the results of this study should overlap with the experiences of those working with health information systems or anyone else who experiences or is aware of technology-induced errors in their work environment (Tracy, 2010). Finally, the fact that participants did not know the questions in advance might have impacted their answers in

a certain way. While providing questions to participants in advance would have enabled them to prepare their answers, some of the questions required spontaneous rather than thoroughly thought-out answers (e.g., defining technology-induced error to measure awareness). In addition, because these interviews were conducted over the phone, it might have impacted the results as well. The lack of ability to observe and read body language during each interview might have influenced the results as well (Jackson & Verberg, 2007). There is also no way of knowing whether the lack of awareness or the lack of agreed upon definition of technology-induced error also exists in other Canadian healthcare organizations that were not represented in this study.

5.11 Conclusion

This study was aimed at exploring the current realities at various Canadian healthcare organizations related to technology-induced error awareness, reduction, and prevention. The expectation of this study was to convey the complexity of technology-induced errors and their great potential to negatively impact patient safety as well as to communicate why there are no simple answers to resolving these issues. The issue of technology-induced errors in healthcare is complex and multidimensional. It requires proper and detailed planning to make sure that healthcare organizations are aware of the problem, understand the problem, are able to quantify the problem by ensuring that it is properly reported, address the problem, and, finally, be able to prevent the problem in the first place. This study focused on exploring the current realities related to technology-induced errors in Canadian healthcare organizations and with individuals representing those organizations. By identifying factors that contribute to technology-induced errors as experienced by current healthcare organizations, the aim was to bring greater awareness

to the issue as well as provide means of beginning to discuss the issue more openly. The author hopes that this discussion will be the catalyst in improving the current issue of technology-induced errors in healthcare.

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Appendix A: Invitation Email

To Whom It May Concern,

We would like to invite you to participate in an interview to learn about how organizations are preventing and addressing errors that may arise from the use of health information technology. The information collected during this interview will be used as a foundation in exploring how organizations are addressing technology-induced errors so that other organizations may learn from these experiences and reduce the risk of future occurrences of such errors across the healthcare system.

The study will take approximately 30 to 60 minutes of your time. You will be asked to complete a short demographic questionnaire and an interview by telephone.

If you consent to participate in this study your identity will be kept strictly confidential. All of the information collected during the study will be kept on a password protected computer and in a locked cabinet at the School of Health Information Science. Your name or any other identifying information will not appear in any presentations or publications from this research. Any identifying information collected during this interview will be removed. As well, published results will contain only anonymous data.

If you are interested in participating in this study, please reply to Paule Bellwood at paulebw@uvic.ca or Elizabeth Borycki at emb@uvic.ca. You may also call 250-472-5432.

If you have any further questions regarding this study, please contact:

Principal Investigator:	Paule Bellwood
Email:	paulebw@uvic.ca
Co-Investigator/Supervisor:	Dr. Elizabeth Borycki, UVic
Telephone:	(250) 472-5432
Email:	emb@uvic.ca
Co-Investigator:	Dr. Andre Kushniruk, UVic
Telephone:	(250) 472-5132
Email:	andrek@uvic.ca

Thank-you for your consideration and we hope you can participate in the study!
Sincerely,

Paule Bellwood

Appendix B: Verbal Consent Form

Health Information Science
University of Victoria

Verbal Consent Form

A Qualitative Study of Technology-Induced Errors in Health Care Organizations

You are invited to participate in a study entitled "The Qualitative Study of Technology-Induced Errors in Health Care Organizations" that is being conducted by Dr. Elizabeth Borycki.

Dr. Elizabeth Borycki is a Faculty Member in the School of Health Information Science at the University of Victoria and you may contact her if you have further questions by Tel: (250) 472-5432 or Email: emb@uvic.ca.

Purpose and Objectives
The purpose of this research project is to determine how organizations are addressing technology-induced errors as well as to explore legal issues involving technology-induced errors and their impact on different healthcare organizations.

Importance of this Research
Research of this type is important because there is an increasing number of health care information systems that are being implemented in health care organizations, e.g. hospitals, physician offices. There is a need to explore how organizations are addressing technology-induced errors so that other organizations may learn from these experiences and reduce the risk of future occurrences.

Participants Selection
You are being asked to participate in this study because you have direct experience in working with these types of issues.

What is involved
If you agree to voluntarily participate in this research, your participation will include completing a demographic questionnaire and participating in a semi-structured interview that will last approximately one hour. The interview will be conducted in person or over the telephone and will focus on the areas of organizational and legal aspects of technology-induced errors in health care. The interviews will be audio recorded and written notes will be taken. Audio recordings will then be transcribed using a word processing program and will be analyzed using content analysis.

Inconvenience
Participation in this study may cause some inconvenience to you, including spending one hour of your time to answer the interview questions.

Risks
There are no known or anticipated risks to you by participating in this research.

Benefits
The potential benefits of your participation in this research include benefits to society and to the state of knowledge as a result of reducing the risk of future technology-induced error occurrences.

Voluntary Participation
Your participation in this research must be completely voluntary. If you do decide to participate, you may withdraw at any time without any consequences or any explanation. If you do withdraw from the study your data will not be used in the analysis and will be destroyed.

Anonymity
In terms of protecting your anonymity, all unique and identifying data will be stripped from the audio recordings during the transcription process. Neither your name nor place of employment will be published anywhere.

Confidentiality
Your confidentiality and the confidentiality of the data will be protected by storing all audio tapes in a locked cabinet at the School of Health Information Science. All transcriptions and data will be stored on a password-protected computer at the School of Health Information Science.

Dissemination of Results
It is anticipated that the results of this study will be shared with others in the following ways: Presentations at scholarly meetings and summary of the results sent directly to the participants.

Disposal of Data
Data from this study will be disposed of after 5 years by erasing the audiotapes and computer files and shredding all paper copies of transcripts and notes.

Contacts
Individuals that may be contacted regarding this study include:
Dr. Elizabeth Borycki, Tel: (250) 472-5432; Email: emb@uvic.ca
Dr. Andre Kushniruk, Tel: (250) 472-5132; Email: andrek@uvic.ca
Paule Bellwood, Email: paulebw@uvic.ca

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca).

Your signature below indicates that you understand the above conditions of participation in this study and that you have had the opportunity to have your questions answered by the researchers.

_____	_____	_____
Name of Participant	*Signature of the Researcher*	*Date*

A copy of the verbal consent form will be e-mailed to the participant if requested.

Appendix C: Background and Demographic Survey

Qualitative Study of Organizational and Legal Aspects Involving

Technology-Induced Errors in Health Care Organizations

Background and Demographic Survey

Thank you for participating in today's interview. To understand the experience and expertise, we would like to invite you to answer to the following demographic questions. All responses will be anonymous. Please do not write your name on this form. The demographic questionnaire will take approximately 5 minutes to complete. Thank you for your participation.

Please tell us a little about yourself:

1. Age: years old
2. Gender: ☐ Male ☐ Female
3. Indicate **your role within your institution or organization:**

_____

_____

_____

_____

4. List all professional and educational programs you have completed after high school, e.g. Health Informatics:

Degree/ Diploma Obtained (e.g. BSc, BA, MD, Masters, PhD, medical specialties)	**Area of Degree/Diploma** (e.g. medicine, health informatics)

5. Indicate how many years of working experience you have had (e.g. information technology, health services, etc.): years

6. Indicate your area of expertise (if applicable) and number of years of practice within this area (e.g. risk management):

_____

_____

_____

_____

7. Have you ever worked with electronic health record systems? ☐ Yes* ☐ No

*7a. If yes, please describe which systems and for how long:

_____

_____

_____

_____

Appendix D: Interview Questions

Semi-structured probes for in-person and telephone interviews

1. Have you heard the term "technology induced error"? If so, please describe.
2. Technology-induced error can be defined as an:

"Error that inadvertently occurs as a result of using a technology (e.g., medication errors that result from using a system)" (Borycki et al., 2009).

Some examples of technology-induced errors may include:

- dispensing an incorrect amount of medication using a CPOE
- indicating an incorrect medication dose using a CPOE
- missing important allergy information that should be clearly displayed on the patient record and prescribing medication to which the patient is allergic

What do you think about this definition? Do you think this is a representative definition?

3. How frequently do you think technology-induced errors occur:
    a. In a typical hospital?
    b. In a regional health authority?
4. Do you think technology-induced errors affect patient safety? In what cases you think they affect patient safety? In what cases you think they do not affect patient safety?
5. Where do you think technology-induced errors come from?
6. What causes technology-induced errors?
7. Have you ever experienced technology-induced errors, read research about them, or heard reports of them? Please describe.
8. Do you think that the following factors have any impact on incidence of technology-induced errors? Why or why not?
    a. Policy at the regional, provincial, or federal level
    b. Health Legislation
    c. Workflow, practices, and terminology that came from the model organization (i.e. the institution the system was initially based on)
    d. Terminologies used at the institution the system was based on, e.g. different acronyms for the same procedure depending on organization
    e. Policies and Procedures
    f. User interface problems
    g. User training
    h. Requirements gathering
    i. Implementation
    j. System testing and user interface testing
9. What do you think can be done about technology-induced errors?
10. Are you aware of any standards, guidelines, or testing approaches for improving the safety of health information systems? Nationally? Internationally? If so, please describe.
11. Are you aware that there is a new Health Canada ruling about the safety of health information technology, where software is being treated as devices? If yes, please describe. What impact do you think this will have on:
    a. Your organization?

    b. Software vendors?
    c. Incidence of technology-induced errors?
    d. Patient safety in general?
12. How does your organization reduce the risk of technology-induced errors?
13. Whose responsibility is it to address the issue of technology-induced errors?
14. To what extent is it a legal or ethical issue or both?
15. What processes or procedures do you currently have in place to:
    a. Prevent technology-induced errors?
    b. Report technology-induced errors?
    c. Address/rectify technology-induced errors?
16. In the U.S., there is something known as the "Hold harmless" clause. It is defined as "[p]rovision in an agreement under which one or both parties agree not to hold the other party responsible for any loss, damage, or legal liability. In effect, this clause indemnifies the parties on a unilateral or reciprocal basis. What do you think about this clause regarding health care technology and software vendors?
17. Any last comments or thoughts about technology-induced errors or the safety of health care information technology in general?

References

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Appendix E: Ethics Approval

University of Victoria

Human Research Ethics Board
Office of Research Services
Administrative Services Building
PO Box 1700 STN CSC
Victoria British Columbia V8W 2Y2 Canada
Tel 250-472-4545, Fax 250-721-8960
Email ethics@uvic.ca Web www.research.uvic.ca

Certificate of Approval

PRINCIPAL INVESTIGATOR:	**Paule Bellwood**	**ETHICS PROTOCOL NUMBER:**	**11-084**
UVic STATUS:	**Undergraduate**	ORIGINAL APPROVAL DATE:	08-Mar-11
UVic DEPARTMENT:	**HEIS**	APPROVED ON:	08-Mar-11
SUPERVISOR:	**Elizabeth Borycki**	APPROVAL EXPIRY DATE:	07-Mar-12

PROJECT TITLE: **Qualitative Study of Technology-Induced Errors in Health Care Organizations**

RESEARCH TEAM MEMBERS: Andrea Kushniruk, Co-Investigator, School of Health Information Science, UVic
Elizabeth Borycki, Supervisor/Co-Investigator, School of Health Information Science, UVic

DECLARED PROJECT FUNDING: **UVic Undergraduate Research Scholarship Funding**

CONDITIONS OF APPROVAL

This Certificate of Approval is valid for the above term provided there is no change in the protocol.

Modifications
To make any changes to the approved research procedures in your study, please submit a "Request for Modification" form. You must receive ethics approval before proceeding with your modified protocol.

Renewals
Your ethics approval must be current for the period during which you are recruiting participants or collecting data. To renew your protocol, please submit a "Request for Renewal" form before the expiry date on your certificate. You will be sent an emailed reminder prompting you to renew your protocol about six weeks before your expiry date.

Project Closures
When you have completed all data collection activities and will have no further contact with participants, please notify the Human Research Ethics Board by submitting a "Notice of Project Completion" form.

Certification

This certifies that the UVic Human Research Ethics Board has examined this research protocol and concluded that, in all respects, the proposed research meets the appropriate standards of ethics as outlined by the University of Victoria Research Regulations Involving Human Participants.

Rachael Scarth

Dr. Rachael Scarth
Acting Associate Vice-President, Research

Certificate Issued On: 08-Mar-11

11-084 Bellwood, Paule

Appendix F: Ethics Renewal

University of Victoria

Human Research Ethics Board
Office of Research Services
Administrative Services Building
PO Box 1700 STN CSC
Victoria British Columbia V8W 2Y2 Canada
Tel 250-472-4545, Fax 250-721-8960
Email ethics@uvic.ca Web www.research.uvic.ca

Certificate of Renewed Approval

PRINCIPAL INVESTIGATOR:	**Paule Bellwood**	**ETHICS PROTOCOL NUMBER:**	**11-084**
UVic STATUS:	**Master's Student**	ORIGINAL APPROVAL DATE:	08-Mar-11
UVic DEPARTMENT:	**HBS**	RENEWED ON:	02-Mar-12
SUPERVISOR:	**Elizabeth Borycki**	APPROVAL EXPIRY DATE:	07-Mar-13

PROJECT TITLE: **Qualitative Study of Technology-Induced Errors in Health Care Organizations**

RESEARCH TEAM MEMBERS: Andrea Kushniruk, Co-Investigator, School of Health Information Science, UVic
Elizabeth Borycki, Supervisor/Co-Investigator, School of Health Information Science, UVic

DECLARED PROJECT FUNDING: **UVic Undergraduate Research Scholarship Funding (previous)**

CONDITIONS OF APPROVAL

This Certificate of Approval is valid for the above term provided there is no change in the protocol.

Modifications
To make any changes to the approved research procedures in your study, please submit a "Request for Modification" form. You must receive ethics approval before proceeding with your modified protocol.

Renewals
Your ethics approval must be current for the period during which you are recruiting participants or collecting data. To renew your protocol, please submit a "Request for Renewal" form before the expiry date on your certificate. You will be sent an emailed reminder prompting you to renew your protocol about six weeks before your expiry date.

Project Closures
When you have completed all data collection activities and will have no further contact with participants, please notify the Human Research Ethics Board by submitting a "Notice of Project Completion" form.

Certification

This certifies that the UVic Human Research Ethics Board has examined this research protocol and concluded that, in all respects, the proposed research meets the appropriate standards of ethics as outlined by the University of Victoria Research Regulations Involving Human Participants.

Rachael Scarth

Dr. Rachael Scarth
Associate Vice-President, Research

Certificate Issued On: 02-Mar-12

11-084 Bellwood, Paule