Chapter 3
Unintended Adverse Consequences of Health IT Implementation: Workflow Issues and Their Cascading Effects

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3.1 Introduction

Health information technology (known as health IT or HIT) has great promise as a means to improve quality of care and patient safety. However, the introduction of health IT can impact healthcare practices in ways that are not planned, leading to unintended consequences. The term "unintended consequences" refers to unforeseen or unpredicted results to a specific action (Campbell et al. 2006). These consequences can be positive, negative, or neutral. In this chapter, we focus on unintended consequences that are found to have a detrimental effect. This is not to say that there are no unanticipated positive effects associated with health IT implementation; within this chapter we simply choose to focus on one aspect that has been more commonly studied.

To date, a considerable body of health IT evaluation research has been devoted to understanding the unintended consequences of health IT. While many papers have reviewed relevant literature in this space (Zadeh and Tremblay 2016; Harrington et al. 2011; Marcilly et al. 2015; Kim et al. 2017; Maslove et al. 2011; Menachemi and Collum 2011; Salahuddin et al. 2016; Niazkhani et al. 2009; Gephart et al. 2015; Bloomrosen et al. 2011; Pirnejad et al. 2010; Voshall et al. 2013; Vanderhook and Abraham 2017; Kuziemsky et al. 2016), the purpose of this chapter is to discuss the unintended consequences in the context of clinical *workflow*. Workflow is a core component of clinical practice because it encompasses all of the activities and processes through which patient care is

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delivered. According to the US Department of Health and Human Services (2017), workflow can broadly be defined as *"the sequence of physical and mental tasks performed by various people within and between work environments. It can occur at several levels (one person, between people, across organizations) and can occur sequentially or simultaneously."*

Understanding workflow in clinical settings is essential to designing and deploying usable health IT. *"A critically important component of an organization's preparation for an HIT implementation is a thorough review of its workflow processes, procedures, and role assignments; yet the complexity of the healthcare workflow makes it resistant to many conventional workflow modeling and automation approaches"* p. 88 (Bloomrosen et al. 2011). Without carefully engineered integration with clinical workflow, health IT systems will not be embraced by end users and they may cause unintended negative consequences that adversely impact quality and safety of patient care (Sheehan and Bakken 2012).

The term unintended consequences in the context of health IT became popularized in the early to mid 2000s by researchers studying the effects of patient care information systems (Paper et al. 2004) and computerized provider/prescriber order entry (CPOE) (Ash et al. 2006). However, the recognition that health IT implementation could bring with it unintended effects was not new, which had been reported in the literature even earlier (e.g., Goldstein et al. 2002). In recent years, unintended adverse consequences (UACs) has become one of the most commonly used terms in the literature to emphasize the detrimental impact of unintended consequences such as more/new work for clinicians and disrupted/altered communication patterns (Campbell et al. 2006; Zheng et al. 2010a; Cresswell et al. 2017).

While many researchers use the term unintended consequences to refer broadly to unanticipated effects related to workflow as a result of health IT implementation (Nanji et al. 2014; Horsky et al. 2006; Harrison et al. 2007; Gephart et al. 2016; Wu et al. 2013; Sergeeva et al. 2016), some researchers call these impacts (Zheng et al. 2010a; Wu et al. 2013; Vishwanath et al. 2010), effects (Vishwanath et al. 2010), residual consequences (Nanji et al. 2014), or simply problems (Horsky et al. 2006). For example, Vishwanath et al. (2010) did not explicitly discuss unintended consequences but talked in depth about the impact of electronic health record (EHR) use on outpatient workflows. Wu et al. (2013), on the other hand, used the term unintended consequences, but they also repeatedly referred to these issues simply as impacts. The varied terminology use suggests a broad interest among the health IT research community in studying unintended consequences. However, it also means that it is difficult to synthesize this body of research because of the lack of consensus on how such issues should be defined and described.

This chapter briefly summarizes the extant literature on how health IT implementation may unintentionally introduce adverse consequences to clinical workflow, with the following two goals. First, we attempt to characterize the chain of impact by distinguishing primary unintended consequences that lead to changes in workflow from secondary unintended consequences that originate from the workflow alterations. Second, we attempt to provide a discussion on the causes of and

some proposed solutions for these workflow-related unintended adverse consequences.

3.2 Characterizing Unintended Consequences

Understanding health IT's impact on workflow can be challenging due in part to the fact that workflow encompasses all activities around clinical care. The introduction of health IT is often associated with direct changes in established workflow, such as new types of work and new task interdependencies, which has been widely noted in the literature (Campbell et al. 2006; Gephart et al. 2015; Kuziemsky et al. 2016). We refer to these as primary unintended consequences. In addition, there are other indirect impacts that occur as a result of these primary consequences. For example, some studies (although varying in their methodological approaches) have found that clinicians may adopt unsafe workarounds in response to disrupted and fragmented workflow, which can lead to an increase in errors resulting in patient safety threats (Ash et al. 2004; Yen et al. 2017; Coiera 2015). This cascading effect, from workflow consequences to other secondary impacts, is illustrated in Fig. 3.1.

3.2.1 Workflow Issues as Primary Unintended Consequences

In many cases, unintended consequences of health IT implementation directly affect the work practices of both clinicians (e.g., physicians, nurses, pharmacists) and non-clinical staff (e.g., medical billing and coders, receptionists, and IT staff), even though the former is far more frequently studied. Unintended consequences to clinicians' workflow, as documented in the literature to date, include new or increased

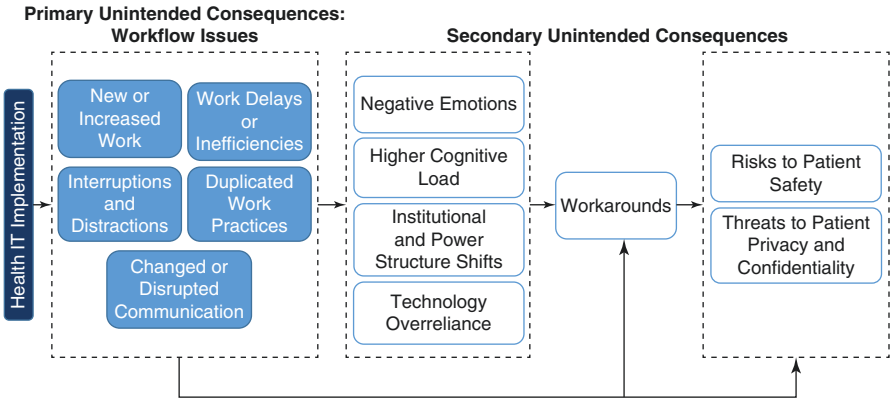

Fig. 3.1 Primary and secondary unintended adverse consequences of health IT

workload (Campbell et al. 2006; Gephart et al. 2016; Van den and Hafkamp 2017); delayed work or time inefficiencies (Zadeh and Tremblay 2016; Zheng et al. 2010a; Horsky et al. 2006; Ramaiah et al. 2012); interruptions or distractions (Zheng et al. 2010a; Nanji et al. 2014; Wu et al. 2013; Sergeeva et al. 2016); duplicated work practices (Campbell et al. 2006; Nanji et al. 2014; Horsky et al. 2006; Gephart et al. 2016; Cifuentes et al. 2015); and changed or disrupted communication (Campbell et al. 2006; Wu et al. 2013).

New or increased work: Health IT can create new types of work or alter the nature of existing work that may lead to increased workload. For instance, one study found that the use of a CPOE system required added steps in order to get to the "patient overview" as compared to the work practices before the CPOE implementation (Campbell et al. 2006). Further, healthcare providers' workload may increase when they are forced to enter new types of information into computerized systems that were not previously required (Campbell et al. 2006; Gephart et al. 2016) and respond to computer-generated alerts that may not contain relevant or helpful information (Campbell et al. 2006). The issue of workload increase appears to disproportionally affect nurses (Gephart et al. 2016; Van den and Hafkamp 2017), even though studies have also found that physicians' administrative workload may also increase due to health IT use (Van den and Hafkamp 2017).

Interruptions and distractions: As a result of added or more fragmented work, health IT may interrupt clinicians' work processes or distract them from performing their clinical tasks. These disruptions may originate from computerized clinical systems (e.g., EHR and CPOE) due to poorly designed alerts and more rigid structured data entry requirements. With the introduction of health IT, clinicians must use a computer to complete certain tasks, which may inherently disrupt their usual workflow. For instance, clinicians may need to spend more time and exert more energy to find a nearby computer workstation to enter patient information (Zheng et al. 2010a), which is an added step not part of the paper-based workflows. Sometimes, computer-based automation may also result in distractions. For example, in the case of pharmacy workflow, a study found that pharmacy staff were disrupted by the need to restock prescriptions that patients never picked up because of an auto-filling feature added to their health IT system (Nanji et al. 2014). More recently, interruptions are also found due to the rapid increase of use of mobile devices in clinical settings. While mobile devices improve access to information and response time (Wu et al. 2013; Sergeeva et al. 2016), they can also become a salient source of disruptions. For instance, the "in the moment" communication afforded by mobile platforms causes frequent interruptions (e.g., imagine a clinician's phone going off every few minutes) (Wu et al. 2013) and disrupts collaborative work practices (Sergeeva et al. 2016). Chapter 7 of this book, *Interruptions and Multitasking in Clinical Work: A Summary of the Evidence*, offers a more in-depth discussion on interruptions and distractions that may be directly related to the adoption of health IT.

Work delays or inefficiencies: Along these same lines, sometimes the introduction of new health IT creates delays in work and decreases time efficiency. For instance, Campbell et al. (2006) reported that CPOE systems could slow the pro-

cess of clinical documentation and ordering. Similarly, in the context of pharmacy workflow, Zadeh and Tremblay (2016) conducted a literature review on studies of e-prescribing systems from 2008 to 2014 and found that 38% of the studies reported reduced pharmacy workflow efficiency as a result of unintended consequences. Further, inefficiencies are not only found internally within a clinical space, but also from breakdowns of IT-based external interactions with insurance companies, laboratories, pharmacies, etc., which may also cause work delays (Ramaiah et al. 2012). While there are discrepancies between some qualitative and quantitative studies with respect to how health IT impacts workflow efficiency, these may be due to how workflow is defined and measured. For example, Zheng et al. (2010a) reported that many time and motion studies had found the impact on workflow efficiency to be negligible; whereas qualitative studies had found consistent perceptions of decreased efficiency. They explained that this discrepancy may be due to the "design of the time and motion studies, which is focused on measuring clinicians' 'time expenditures' among different clinical activities rather than inspecting clinical 'workflow' from the true 'flow of the work' perspective". Therefore, they developed a set of new methods (e.g., workflow fragmentation assessments, pattern recognition, and data visualization) to assess workflow efficiency and found that the implementation of a CPOE system caused a higher frequency of task switching and more fragmented workflow. This work suggests that analyses merely focusing on time utilization may not be adequate to capture workflow inefficiencies.

Duplicated work practices: Another major unintended consequence related to clinical workflow is duplicated work practices. Sometimes health IT requires clinicians to enter redundant information (Gephart et al. 2016; Cifuentes et al. 2015) or copy data from paper forms into the system (Horsky et al. 2006). For instance, Cifuentes et al. (2015) reported that clinicians often needed to double-enter their work into multiple computerized systems that were not interconnected. In other cases, health IT causes duplicated results, such as with the case of medications. For example, in Campbell et al.'s (2006) early work, they found that emergency orders were often duplicated because they were entered into the CPOE system and then phoned in to ensure efficiency. Similarly, in more recent studies, Nanji et al. (2014) found that medication prescriptions were being dually transmitted—once through fax and once through the e-prescribing system—which often resulted in the same medications being filled more than once for each patient.

Changed or disrupted communication: Communication is critical to clinical work and workflow, which may be altered or disrupted as the result of health IT use. CPOE systems, for example, may inhibit interpersonal communication because ordering information is now conveyed through electronic means that eliminate face-to-face interactions, during which important miscommunication and omissions may be discovered (Campbell et al. 2006). Similarly, Wu et al. (2013) conducted a study on the use of electronic communication tools, particularly smartphones, in clinical settings, and found that they could cause a decrease in verbal communication and negatively impact the relationships among clinicians. Thus, instead of promoting effective communication among healthcare providers and staff, health IT systems often provide only an illusion of communication

whereby it is assumed the intended recipient will view and act upon the information entered into the system. However, this may not always be the case in reality (Campbell et al. 2006).

3.2.2 Secondary Unintended Consequences Resulting from Workflow Issues

As a result of the workflow issues, clinicians often face secondary consequences, such as negative emotions, higher cognitive load, shifts in institutional and power structure, and overreliance on technology. When clinicians are overburdened or upset, they may resort to workarounds in an attempt to ease these secondary consequences. These workarounds, and the workarounds that directly result from the workflow issues, can negatively impact patient safety and privacy.

3.2.2.1 Adverse Effects on Clinicians

Workflow issues that result from health IT adoption can impact clinicians in many unintended and negative ways, including provoking negative emotions (Campbell et al. 2006; Sittig and Kaalaas-Sittg 2005), increasing task fragmentation (Zheng et al. 2010a; Yen et al. 2017), changing institutional and power structure (Campbell et al. 2006), and creating an overreliance on technology (Campbell et al. 2006). As healthcare providers try to learn an new computerized system and contest with changes to their work processes, they may experience guilt, annoyance, sadness, hostility, and disgust (Sittig and Kaalaas-Sittg 2005). These unexpected and negative emotions often occur due to disruptions to clinical workflow and negative feedback from the system (Sittig and Kaalaas-Sittg 2005). Not only are these negative feelings unpleasant for clinicians, but they may also make it difficult for clinicians to attend to complex clinical tasks (Campbell et al. 2006; Sittig and Kaalaas-Sittg 2005).

Changes and disruptions to established workflow can also result in task fragmentation reflected as higher frequencies of task switching and multitasking (Zheng et al. 2010a; Yen et al. 2017). This can be disruptive to clinicians' work and are often associated with increased cognitive load and unnecessary physical activities (Yen et al. 2017; Laxmisan et al. 2007; Zheng et al. 2010b). For example, frequent login and logout actions, interruptive alerts, irrelevant reminders, and abrupt phone calls can all lead to more fragmented workflows and higher chance for errors (Yen et al. 2017; Coiera 2015).

By requiring added work and altering the ownership of certain clinical activities and tasks, health IT can impact individuals' roles and responsibilities in an organization (Van den and Hafkamp 2017), leading to changes in institutional and power structure (Campbell et al. 2006). For instance, CPOE systems redistribute work through role-based authorization, which rigidly controls who can do what (Campbell

et al. 2006). Further, role misfits could occur where individuals experience reduced autonomy (Van den and Hafkamp 2017). An example is that after the implementation of a new EHR system, nurses must wait for an official order from a physician placed through the system in order to remove a patient's IV, which could be independently performed by nurses in the past (Van den and Hafkamp 2017). This change shifts the power structure and could create resentment between different types of medical professionals (Campbell et al. 2006).

As clinicians become accustomed to health IT, they may also develop an overreliance on technology (Campbell et al. 2006; Shepard 2017), where certain clinical tasks simply can no longer be accomplished without technology. This can be problematic when technology fails. It is inevitable that health IT will experience downtimes, both planned and unplanned (Shepard 2017; Kashiwagi et al. 2017). In the event of a system failure, clinicians may no longer have the relevant information or knowledge (e.g., standard dosages and medication contradictions) to perform a task, which they relied on health IT to provide (Campbell et al. 2006). This can result in delayed care and/or increased patient safety risks (Campbell et al. 2006; Kashiwagi et al. 2017; Larsen et al. 2018).

3.2.2.2 Workarounds

Workarounds are mitigating strategies commonly employed by clinicians to overcome barriers to their work introduced by a variety of factors, including primary unintended consequences and their secondary effects. Workarounds can be individual, managerial, or artifact-based, depending on who initiates the workaround and how it is enacted. Common examples of workarounds include using paper and other software systems as intermediaries (Cresswell et al. 2017; Menon et al. 2016) and staying logged into the system under a coworker's credential to save time (Ser et al. 2014). In the context of test result management, Menon et al. (2016) found that among the primary care clinicians studied who used workarounds, 70% reported using paper-based methods and 22% reported using a combination of paper and computer-based approaches.

Sometimes workarounds can become a routine practice to address workflow issues (Salahuddin et al. 2016). For instance, to combat inefficiencies and to facilitate care coordination, clinicians may write down patient information on a piece of paper (Menon et al. 2016) or take photos of the screen of a computer workstation (Eikey et al. 2015). Generally, workarounds are aimed at alleviating secondary consequences that emerge as a result of workflow issues, rather than addressing the underlying workflow issues directly. For example, changes to work processes due to IT use may increase the cognitive load of clinicians, requiring them to use paper-based methods as a memory aid (Menon et al. 2016).

Many researchers have studied workarounds as part of the attempt to better understand disruptions to clinical workflow (Voshall et al. 2013; Cresswell et al. 2017; Ramaiah et al. 2012; Menon et al. 2016). Workarounds are an important phenomenon in this context, as they often signal unaddressed workflow issues. Some

workarounds, e.g., those circumventing IT-enforced documentation requirements or patient safety protocols, may also lead to additional adverse consequences (Cresswell et al. 2017; Menon et al. 2016). While workarounds are often informal practices to mitigate workflow issues, they can also become formal organizational mandates when a direct solution is not readily available (Cresswell et al. 2017).

3.2.2.3 Risks to Patient Safety

The most concerning adverse impact as a result of workflow issues and/or unsafe workarounds is added risks to patient safety (Cresswell et al. 2017; Gephart et al. 2016; Menon et al. 2016). Disruptions to workflow can increase the likelihood of errors, leading to serious adverse events (Campbell et al. 2006; Pirnejad et al. 2010; Voshall et al. 2013; Cresswell et al. 2017; Nanji et al. 2014; Horsky et al. 2006; Ash et al. 2004; Menon et al. 2016). Poor usability of health IT also contributes to the problem. For example, poorly designed software user interfaces may make it much easier for clinicians to select the wrong option or input an order for the wrong patient (Ash et al. 2004; Schiff et al. 2016). Schiff et al. (2016) provided an overview of common design problems of CPOE, including an illustration of how the overwhelming number of acetaminophen choices displayed on a computer screen could facilitate new types of errors. In addition, health IT requires complete and structured data, which can also cause cognitive overload that makes clinicians more susceptible to making mistakes (Ash et al. 2004; Yen et al. 2017; Coiera 2015; Chao 2016).

3.2.2.4 Threats to Patient Privacy and Confidentiality

Lastly, workflow issues and unsafe workarounds can adversely affect patient privacy and confidentiality. Particularly, the use of workarounds such as paper notes, screenshots, and photos to improve memory and efficiency can threaten patient privacy and confidentiality by recording and transferring sensitive patient information in an unsecure manner. Although there are often privacy policies and security measures in place in clinical environments, clinicians may work around them when they deem these policies and measures as inhibitors to their work practices (Eikey et al. 2015; Murphy and Reddy 2014; Chen and Xu 2013).

3.3 Causes and Solutions of Workflow Issues

We now shift the focus to the causes of workflow issues and briefly discuss some solutions that have been proposed in the literature. Most commonly, workflow issues occur when there is poor alignment between work practices and health IT design (Campbell et al. 2006; Horsky et al. 2006; Gephart et al. 2016). Health IT

tends to rigidly model workflow according to organizational policies and regulatory requirements, which may not necessarily reflect the reality of day-to-day clinical practice (Campbell et al. 2006). Nuanced, non-linear, complex, and sometimes invisible processes are not easily incorporated in IT design. Health IT also tends to neglect the varied nature of workflow needs; that is, the work practices around the same task may be very different depending on an individual's role, the patient's conditions, etc. (Campbell et al. 2006). Health IT changes work practices, and work practices and social systems around health IT impact how they are used (Harrison et al. 2007).

Affordances of newly introduced technologies may also result in workflow issues. In some cases, barriers to workflow are introduced intentionally for valid reasons; for example, authentication requirements and automatic system timeouts (Eikey et al. 2015; Murphy and Reddy 2014; Chen and Xu 2013) are "limitations" designed purposefully to protect data security and patient privacy, even though they may cause undesirable delays and workflow disruptions. In addition, sometimes the affordances of technology adapted for clinical settings make them prone to disrupt workflow. For instance, smartphones could easily become a source of workflow interruption because of their ability to allow healthcare professionals to contact each other "in the moment" (Wu et al. 2013). Similarly, despite benefits, a study showed that use of iPods in the operating room can be distracting because they are by design fun and entertaining; they allow healthcare providers to do personal activities that may divert their attention from clinical work (Sergeeva et al. 2016).

Additionally, workflow issues may stem from a lack of standardization across different healthcare organizations, such as hospitals, specialty clinics, laboratories, pharmacies, and insurance companies (Ramaiah et al. 2012). While health IT at one site may be well-integrated with the local work practices, clinicians' and staff's work may be negatively impacted when there are barriers to effectively communicating with other entities through health IT. Unfortunately, while significant advancements of health information exchange have been made in recent years, the interoperability between different health IT systems remains poor, which could cause delays and disruptions (Ramaiah et al. 2012).

Throughout the literature, there are numerous proposed solutions to preventing and improving workflow issues and mitigating their unintended adverse effects. First, it has been repeatedly shown that developing a thorough understanding of workflow in clinical settings, both before and after health IT implementation, is critical (Campbell et al. 2006; Gephart et al. 2016). This requires health IT designers and implementers shift their focus from "anticipated" use to actual use (Harrison et al. 2007) and consider multiple perspectives when designing and evaluating systems (Wu et al. 2013). Some researchers have also argued for the importance of considering the sociotechnical integration of health IT with its use context. For instance, Harrison et al. (2007) developed the Interactive Sociotechnical Analysis (ISTA) framework as a means to better understand healthcare organizations as a sociotechnical system and "stop viewing HIT innovations as things, but instead treat them as elements within unfolding processes of sociotechnical interaction" p. 543.

Constantly gathering feedback from frontline clinicians and staff is also crucial to identify unintended workflow issues and making necessary health IT or organizational changes (Campbell et al. 2006). Such feedback should be taken seriously and incorporated in a timely manner into a redesign to customize health IT to better fit end users' workflow (Gephart et al. 2016). As part of this feedback, workarounds also need to be transparent. By tracking workarounds and making them more visible, we can determine if there is solid rationale justifying their use and if actions should be taken to formalize them as part of organizational processes (Cresswell et al. 2017) or to mitigate their risks (Cresswell et al. 2017). The design of IT systems is not stagnant and thus, we must iteratively make design revisions as we discover more about clinical workflow and how it is affected by the use of health IT (Campbell et al. 2006).

3.4 Future Work

Designing a health IT system that is perfectly aligned with clinical workflow is very challenging. This is particularly true for *unintended* workflow disruptions which, by definition, cannot be easily anticipated by software designers and implementers. That said, developing a thorough understanding of the clinical work and clinical workflow in the setting where the system will be deployed is possible and can help to mitigate undesirable effects (Harrison et al. 2007). Then, post-implementation, we need close collaboration between system designers, developers, implementers, clinician champions, and all other end users to monitor adoption and appropriation and make necessary changes to the system or use additional training to improve workflow and ease secondary consequences. Systems must also be flexible enough to be quickly adapted, capable of incorporating feedback and suggestions. That is, all health IT systems must be treated as a constant "work in progress" in order to maximize their benefits while minimizing potential harm to clinicians, staff, and patients.

Further, it should be acknowledged that radical workflow change as a result of health IT adoption is inevitable. New, IT-enabled processes necessitate new care models and new workflow patterns. However, as demonstrated in the literature, many workflow disruptions associated with health IT implementation could have been avoided, and some of the adverse effects are due to the lack of communication with clinicians and staff on change management and setting up the right expectations. Thus, we need to develop ways to ease end users' negative emotions, reduce their cognitive load, alleviate concerns about power and role changes, and ensure they do not become over-reliant on technology. Additionally, we need to pay particular attention to unsafe workarounds and their potential detrimental effects on patient safety, privacy, and confidentiality.

This chapter represents a first step toward understanding and unpacking the relationship between what we have termed as primary and secondary unintended consequences. However, in studying unintended consequences of health IT related to workflow, we have to take a holistic approach that addresses systems, users, mana-

gerial issues, and the context and considers the secondary or indirect effects resulting from primary workflow changes. We hope this chapter sparks more research on the different categories of unintended consequences, as well as the causal and perhaps even cyclical connections between them.

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