International Journal of Medical Informatics 97 (2017) 1–11

Contents lists available at ScienceDirect

International Journal of Medical Informatics

journal homepage: www.ijmijournal.com

Clinical reasoning in the context of active decision support during medication prescribing

Jan Horsky (Ph.D.)[a,b,*], Jos Aarts (Ph.D.)[c,d], Leonie Verheul (M.Sc.)[d], Diane L. Seger (R.Ph.)[a], Heleen van der Sijs (PharmD, Ph.D.)[e], David W. Bates (M.D., M.Sc.)[a,b]

[a] Division of General Internal Medicine and Primary Care, Brigham &Women's Hospital, Boston, MA, United States
[b] Harvard Medical School, Boston, MA, United States
[c] Department of Biomedical Informatics, SUNY Buffalo, NY, United States
[d] Institute of Health Policy and Management, Erasmus University Rotterdam, The Netherlands
[e] Department of Hospital Pharmacy, Erasmus Medical Center, Rotterdam, The Netherlands

ARTICLE INFO

Article history:
Received 24 July 2015
Received in revised form 20 August 2016
Accepted 7 September 2016

Keywords:
Patient safety
Electronic health records
Clinical decision support systems
Human-computer interaction
Computer-assisted decision making
Alerts
User-centered design

ABSTRACT

Objective: Describe and analyze reasoning patterns of clinicians responding to drug-drug interaction alerts in order to understand the role of patient-specific information in the decision-making process about the risks and benefits of medication therapy. Insights could be used to inform the design of decision-support interventions.
Methods: Thirty-two clinicians working with five EHRs in two countries completed sets of six medication orders each and responded to high- and low-severity drug-drug interaction alerts while verbalizing their thoughts in a standard think-aloud protocol. Tasks were recorded and analyzed to describe reasoning patterns about patient-risk assessment and strategies to avoid or mitigate it.
Results: We observed a total of 171 prescribing decisions. Clinicians actively sought to reduce risk when responding to high-severity alerts, mostly by monitoring patients and making dose adjustments (52 alerts, 40%). In contrast, they routinely left prescriptions unchanged after low-severity alerts when they felt confident that patients would tolerate the drug combination and that treatment benefits outweighed the risks (30 alerts, 71%). Clinicians used similar reasoning patterns regardless of the EHR used and differences in alert design.
Discussion: Clinicians conceptualized risk as a complex set of interdependent tradeoffs specific to individual patients and had a tendency not to follow advice they considered of low clinical value. Omission of patient-specific data, which was not shown in alerts or included in trigger logic, may have contributed to the constancy of reasoning and to similarities in risk-control strategies we observed despite significant differences in interface design and system function.
Conclusion: Declining an alert suggestion was preceded by sometimes brief but often complex reasoning, prioritizing different aspects of care quality and safety, especially when the perceived risk was higher. Clinicians believed that the risk indicated in drug-drug interaction alerts needs to be interpreted as one factor in the broader context of care, specific to a patient.

1. Introduction

Patient injuries due to preventable medication errors are reported in hospital and ambulatory care at the rate of over 1.5 million per year in the United States [1]. Serious errors occur at any point of treatment although most originate during prescribing, even with the use of electronic ordering systems [2,3], and may result in adverse drug events (ADEs) that cause substantial morbidity and sometimes mortality [4,5]. Clinical decision support (CDS) systems that automatically critique submitted orders and intervene when a potentially unsafe prescription is detected reduce the risk of this type of error [6,7]. However, the extent to which current

* Corresponding author at: 93 Worcester St., Suite 201Wellesley, MA 02481, United States.
E-mail address: jhorsky@partners.org (J. Horsky).

http://dx.doi.org/10.1016/j.ijmedinf.2016.09.004
1386-5056/

health information technology (HIT) improves prescribing behavior of clinicians or helps pharmacists identify errors is uncertain [8–10]. There is strong research evidence that on many current systems the majority of drug-drug and drug-allergy interaction alerts are routinely disregarded or considered to be only indirectly relevant to any specific patient [11,12]. Some electronic health record (EHR) systems can inadvertently increase the risk of error by making human interaction unnecessarily difficult and by intensifying cognitive and attentional effort when poorly designed interfaces display critical information and warnings in ambiguous or inconsistent ways [13–16]. However, few empirical studies of ADEs directly attributable to the effects of HIT use have been done to date [15,17].

The high proportion of alerts that clinicians consider to be uninformative or only marginally useful indicates that CDS is not yet a fully mature technology. Alert override is today a typical rather than an exceptional response, often following a medically appropriate decision, even though the risk of missing an important warning increases [18–21]. Low specificity of rules that produce overly active automatic interventions lead over time to learned behaviors such as workarounds, inappropriate shortcuts and hasty closing of dialog boxes without sufficient time to read their content. Poor visual and interactive attributes of alerts that are not integrated well into common workflows increase the risk that a critical warning will be unintentionally dismissed without due consideration [22]. A deleterious and insidious secondary effect that also emerges is the gradual reduction of confidence in any warning the EHR provides, irrespective of its indicated importance [23,24].

One approach to reducing excessive alerting is to adjust arbitrarily low triggering thresholds to adequate and effective levels [25,26] and to remove inconsistencies found in many databases [27,28]. Experts generally recommend refining knowledge bases so that interruptive alerts are displayed only for a subset of truly significant interactions with a potential to harm [29]. Short lists of drug pair candidates for this category have been recently published [30] but they cover only a minority of interactions. Risk severity criteria also differ considerably from one institution to another [31]. Suppressing an entire class of alerts would be dangerous [32] and local customization of databases requires special expertise and costly work that is seldom done outside of large institutions, even if vendors allow such modifications [33–35].

Another way to reduce the number of irrelevant alerts is to make general trigger rules more specific by incorporating existing patient data [36]. Information from records such as age, gender, problems, comorbidities, active medications or laboratory and test results can be used to revise a general risk assessment based on population criteria to be more relevant to an individual patient, especially when combined with therapy details such as dose or duration and with pharmacogenomics [37]. However, few systems today can incorporate multiple data points from the EHR into their decision logic in a more than rudimentary way. Although some success was recently reported in a controlled pre-post intervention study with a home-grown EHR [38], the prospect of successfully developing and curating sophisticated automated interventions decreases with escalating rule complexity [39,40].

Rather than evaluating the. use of patient data for the refinement of trigger algorithms, our goal was to investigate how medical context is used by clinicians responding to drug-drug interaction alerts to assess risk to the patient and to find safer alternatives. We describe patterns of clinical reasoning about risk factors associated with drug interactions that include delayed or less effective treatment, care priorities and uncertainty. Our broader objective was to review assumptions about optimal CDS design [8,41–43] by collecting empirical evidence and to contribute new insights. Understanding how electronic prescribing is done in the context of routine clinical work and how clinicians reason about the risks and benefits of each treatment decision is essential for developing more effective CDS interventions [44].

2. Methods

This study of interactive behavior and reasoning was designed as a partial simulation of a patient encounter that followed a standardized scenario. Clinicians were asked to prescribe medications for a fictitious patient who had a complete electronic record with allergies, laboratory results, a problem list and several active medications. Newly entered drug orders from the scenario were set to trigger drug-drug interaction alerts designated as high or low severity. We asked clinicians to respond to any alerts the same way they would in their practice and to verbalize their thoughts while completing the tasks. If a certain action could not be done within the confines of the simulation (e.g., calling a pharmacist or a colleague for consultation) they would simply describe their intent and how they would proceed after the information was obtained.

2.1. Study settings, EHR systems and participants

We studied the interaction of clinicians with five systems at four locations: one in the United States (US) and three in The Netherlands (NL), over a four-month period between January and May, 2014. Three EHRs were commercial products and two were developed internally at a large academic institution. The systems differed substantially in human interface design and the way alerts were presented to clinicians. For example, alerts on some systems included more details on safety risks associated with the interaction than others and differed in the way they were accessed (e.g., via a link, button, new tab). All automatically intervened when drug-drug and drug-allergy interactions were detected during entry (Table 1).

We recruited seven physicians through intra-institution advertising as a sample of convenience for each of the two systems in the United States and six physicians for each system in The Netherlands; a total of 32 participants. There were 15 hospitalists (47%), 13 specialists (41%) and 4 general practitioners (12%). The majority (65%) had 3 years of professional experience or more and over 80% used their respective EHRs for medication prescribing on every workday (Table 2).

Each test session took place in an empty room with a standard clinical workstation running the local EHR and lasted about 40 min, including a 10-min introduction and scenario review in the presence of a researcher who monitored the process and asked follow-up questions at the end. Morae 3.2 software [45] was used to record the live content of monitor screens as well as the verbalizations and headshots of participants via a webcam with an integrated microphone. Audio tracks were transcribed (and translated to English where necessary) and the entire audiovisual content analyzed. Statistical tests were done with SAS, version 9.3 [46]. This study was approved by the Institutional Review Board at the Brigham & Women's Hospital in Boston (Protocol # 2011P002593/BWH). Participants volunteered their time and were not remunerated.

2.2. Analysis and coding scheme development

The collected data were used to describe decisions about treatment modifications after a DS intervention and reasoning patterns about the relative safety of possible alternatives. Observations of individual clinicians interacting with a system were aggregated for analysis within the socio-technical explanatory framework [47,48]. The think-aloud method [49], frequently used in healthcare for the purpose of finding design and usability problems with HIT, was used in this study to gain insight into clinical reasoning.