Journal of Biomedical Informatics 83 (2018) 40–53

Contents lists available at ScienceDirect

Journal of Biomedical Informatics

journal homepage: www.elsevier.com/locate/yjbin

Comprehensive methodology to monitor longitudinal change patterns during EHR implementations: a case study at a large health care delivery network

Tiago K. Colicchio[a,*], Guilherme Del Fiol[b], Debra L. Scammon[c], Julio C. Facelli[b], Watson A. Bowes III[b,d], Scott P. Narus[b,d]

[a] Informatics Institute, University of Alabama at Birmingham, AL, USA
[b] Department of Biomedical Informatics, University of Utah, Salt Lake City, UT, USA
[c] Department of Marketing, David Eccles School of Business, University of Utah, Salt Lake City, UT, USA
[d] Medical Informatics, Intermountain Healthcare, Salt Lake City, UT, USA

ARTICLE INFO

Keywords:
Electronic health records
Medical informatics applications
Adoption
Outcome assessment
Interrupted time series analysis

ABSTRACT

Objective: To test a systematic methodology to monitor longitudinal change patterns on quality, productivity, and safety outcomes during a large-scale commercial Electronic Health Record (EHR) implementation.

Materials and Methods: Our method combines an interrupted time-series design with control sites and 41 consensus outcomes including quality (11 measures), productivity (20 measures), and safety (10 measures). The intervention consisted of a phased commercial EHR implementation at a large health care delivery network. Four medium-size hospitals and 39 clinics from 5 geographic regions implementing the new EHR were compared against a parallel control consisting of one medium-size and one large hospital and 10 clinics that had not implemented the new EHR at the time of this study. We collected monthly data from February 2013 to July 2017.

Results: The proposed methodology was successfully implemented and significant changes were observed in most measured variables. A significant change attributable to the intervention was observed in 12 (29%) measures in three or more regions; in 32 (78%) measures in two or more regions; and in 40 (98%) measures in at least one region. A similar pattern (i.e., same impact in three or more regions) was detected for nine (22%) measures, a mixed pattern (i.e., same impact in two regions, and different impact in other regions) was detected for nine (22%) measures, and an inconsistent pattern (i.e., did not detect the same impact across regions) was detected for 23 (56%) measures.

Discussion: Using a formal methodology to assess changes in a set of consensus measures, we detected various patterns of impact and mixed time-sensitive effects. With an increasing adoption of EHR systems, it is critical for health care organizations to systematically monitor their EHR implementations. The proposed method provides a robust and consistent approach to monitor EHR implementations longitudinally allowing for continuous monitoring after the system becomes stable in order to avoid unexpected effects.

Conclusion: Our results and methodology can guide the broader medical and informatics communities by informing *what* and *how* to continuously monitor EHR impact on quality, productivity, and safety.

1. Background and significance

Although Electronic Health Record (EHR) systems have recently achieved widespread adoption in the U.S. [1,2], investigations of their impact rarely focus on the effects introduced by EHR implementations, and have not contributed to increasing our understanding of the impact of EHRs on care outcomes [3]. The literature investigating such an impact is also increasing [4,5]; however, current evaluations frequently produce mixed or even negative results [6,7], leaving unanswered questions as to the impact of health information technology (health IT) adoption [8]. Contributing factors to these gaps include poor descriptions of context of the settings and interventions tested, and the use of a narrow set of study-specific measurements, creating obstacles to the comparison of outcomes across studies [9]. In addition, despite the fact that EHR implementations introduce sociotechnical changes that iteratively evolve over time [10], exposing users to a learning curve of

* Corresponding author at: 1900 University Boulevard, Suite 142, Birmingham, AL 35294-3412, USA.
E-mail address: tcolicchio@uabmc.edu (T.K. Colicchio).

https://doi.org/10.1016/j.jbi.2018.05.018
Received 15 February 2018; Received in revised form 2 May 2018; Accepted 28 May 2018
Available online 29 May 2018

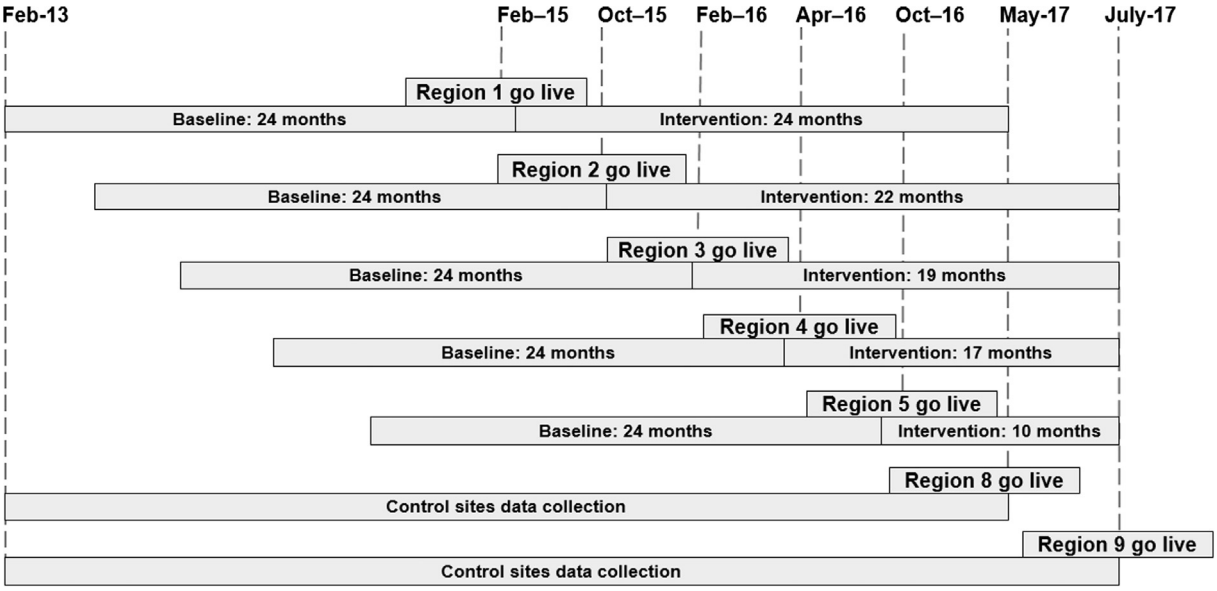

Fig. 1. Illustration of study design and EHR go live in intervention and control regions.

up to two years [11], health IT evaluations frequently use simple research designs such as pretest-posttest comparisons that do not consider the longitudinal characteristic of EHR implementations [12–15]. There is a need to overcome these methodological limitations to: (1) increase the capacity of future systematic reviews – and potential meta-analyses – to compare context-related information, interventions, and outcomes across studies; and (2) improve our understanding of the impact of health IT interventions on quality, productivity, and safety outcomes with continuous and systematic monitoring of such interventions [3,5].

We have developed a systematic methodology to detect near real-time performance changes during EHR implementations [16]. The methodology includes a robust inventory of outcome measures likely impacted by health IT interventions. The measures were retrieved from the literature [9] and suggested by subject-matter experts [17]. Our method was previously used in a pilot longitudinal analysis of a commercial EHR implementation [16]. In the present study, we expand our analysis by assessing more measures and care settings from geographically dispersed regions of the same implementation.

2. Objective

The objective of this study is to test a systematic and potentially replicable methodology to monitor longitudinal change patterns during EHR implementations. Health IT interventions – especially implementation of multifunctional commercial EHR systems – are highly complex interventions consisting of multiple small interventions. In this study, we aimed to demonstrate that the proposed methodology can both prospectively and retrospectively identify patterns of impact at an organization implementing an EHR; we do not focus on evaluating whether clinical impacts can be attributed to the new EHR, nor do we

Table 1
Detailed description of ambulatory measures.

Measure	Description	Criteria
Quality of care measures		
Blood pressure control	Rate of diabetes patients with blood pressure under control	N: diabetes patients with blood pressure under control D: diabetes patients with blood pressure measured
Diabetes Bundle	Composite measure for diabetes control	N: patients in compliance with all diabetes bundle items (hemoglobin A1c; blood pressure; retinopathy screening; nephropathy screening) D: eligible diabetes patients
Hemoglobin A1c control	Rate of diabetes patients with hemoglobin A1c under control	N: diabetes patients with Hemoglobin A1c below 8% D: diabetes patients with Hemoglobin A1c measured
Medication for Asthma	Rate of asthma patients using appropriate medication	N: asthma patients who received controller reliever medication D: eligible asthma patients
Productivity measures		
Employee movement rate	Rate of employees moved permanently to a different facility or department	N: ambulatory employees transferred to a different work location D: total ambulatory employees
Employee turnover rate	Rate of employee contracts terminated	N: ambulatory employees with voluntary contract termination D: total ambulatory employees
Laboratory test orders	Number of orders of laboratory tests	Number of orders of laboratory tests
New patient visits	Rate of new patient (new to Intermountain Healthcare) visits to ambulatory settings	N: new patient visits D: total patient visits
Patient visits	Number of patient visits to ambulatory settings	Number of patient visits to ambulatory care clinics
Radiology test orders	Number of orders of imaging tests	Number of imaging tests completed
Time documenting in EHR	Average time spent by provider documenting in electronic health records per patient	Average time spent per provider documenting (any interaction within a patient chart) in electronic health records per patient – Monday to Friday – 8 am to 6 pm
Time documenting in EHR after hours	Time spent by provider documenting in electronic health records after work hours	Average time spent per provider documenting (any interaction within a patient chart) in electronic health records per patient after 6 pm

Abbreviations: N: numerator; D: denominator.