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Research and Applications

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Influence of simulation on electronic health record use patterns among pediatric residents

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ABSTRACT

Objective: Electronic health record (EHR) simulation with realistic test patients has improved recognition of safety concerns in test environments. We assessed if simulation affects EHR use patterns in real clinical settings.

Materials and Methods: We created a 1-hour educational intervention of a simulated admission for pediatric interns. Data visualization and information retrieval tools were introduced to facilitate recognition of the patient's clinical status. Using EHR audit logs, we assessed the frequency with which these tools were accessed by residents prior to simulation exposure (intervention group, pre-simulation), after simulation exposure (intervention group, post-simulation), and among residents who never participated in simulation (control group).

Results: From July 2015 to February 2017, 57 pediatric residents participated in a simulation and 82 did not. Residents were more likely to use the data visualization tool after simulation (73% in post-simulation weeks vs 47% of combined pre-simulation and control weeks, $P <. 0001$) as well as the information retrieval tool (85% vs 36%, $P < .0001$). After adjusting for residents' experiences measured in previously completed inpatient weeks of service, simulation remained a significant predictor of using the data visualization (OR 2.8, CI: 2.1-3.9) and information retrieval tools (OR 3.0, CI: 2.0-4.5). Tool use did not decrease in interrupted time-series analysis over a median of 19 (IQR: 8-32) weeks of post-simulation follow-up.

Discussion: Simulation was associated with persistent changes to EHR use patterns among pediatric residents.

Conclusion: EHR simulation is an effective educational method that can change participants' use patterns in real clinical settings.

Key words: education, medical, electronic health records, simulation training

BACKGROUND AND SIGNIFICANCE

While electronic health records (EHRs) occupy a central role in the delivery of patient care, clinicians receive very limited training in effective use of the EHR. In a survey of providers across 5 professional societies, nearly half of clinicians reported no more than 3 days of EHR training.[1] Many medical students and advanced practice nurses receive no EHR training at all.[2] To the extent that training exists, many programs often rely on passive learning methods, including classroom/lab didactic lectures, rote scripts, online e-learning modules, or shadowing experienced users.[3] Both in terms of content and approach, current EHR training may not effectively prepare clinicians for the complex clinical tasks they are expected to perform.[4] Inadequate EHR utilization has been implicated in patient safety concerns or "e-iatrogenesis."[5,6] An analysis of EHR user logs suggested that clinicians who made dosing errors were navigating the EHR haphazardly, applying a "trial and error" approach to computerized provider order entry instead of a skilled, consistent strategy.[7] Even those felt to be "clinical experts" often miss important safety concerns during EHR simulations.[8,9]

In considering how to effectively educate clinicians, cognitive load theory indicates that active learning methods are more likely to transfer skills to real environments.[10] Active learning improves transfer from the training environment to actual practice through the generation effect, in which trainees must make active choices and experience the consequences instead of passively following a directed script.[11] In a survey of 6 exemplary EHR implementations, all 6 institutions identified active learning as a key contributor to successful training.[12] Simulation in medical education that takes advantage of active learning concepts has seen rapidly increasing popularity with evidence supporting improved educational outcomes.[13–17]

Recently, EHR simulation has gained traction to more actively engage clinicians in EHR training. However, producing realistic cases that replicate the cognitive load of real clinical practice requires substantial resources,[3] necessitating evidence of improved educational outcomes to justify the costs. Stephenson et al.[18] showed that EHR simulation participants recognized more errors in their second simulation case than their first, indicating that effective use of the EHR is a learnable skill. However, to our knowledge, no studies demonstrate the association of EHR simulation with clinicians' behaviors in actual clinical practice. In this study, we describe the association between participating in an EHR simulation based on a case of neonatal hyperbilirubinemia and subsequent EHR use patterns of pediatric residents at an academic medical center.

MATERIALS AND METHODS

Design and setting

Within the pediatric residency program at Children's Hospital of Philadelphia, we performed a quasi-experimental study using both an untreated control group and pre- and post-intervention samples in the intervention group.[19] We sampled EHR use patterns during weeks of inpatient service. Our control group was composed of residents who were never exposed to simulation. In the intervention group (residents who completed the simulation), our pre-intervention samples were EHR use patterns during weeks of inpatient service prior to simulation participation, while our post-intervention samples were EHR use patterns during weeks of inpatient service after simulation participation. In this design, the post-intervention samples (exposed) were contrasted with the combined control group samples and pre-intervention samples (unexposed) in multivariable regression. Additionally, the post-intervention samples were compared with the pre-intervention samples in interrupted time-series analysis.

Educational intervention

We created an informatics simulation curriculum for first-year pediatric residents aimed at increasing their capacity to detect patient safety concerns using the EHR. Once a month beginning October 30, 2015, 4 to 6 first-year residents on the General Pediatrics/Hematology team participated in a 1 hour teaching session focused on a simulated case in the EHR aimed at increasing awareness during emergency department (ED) to inpatient handoffs. Residents were given 12 minutes to review the chart, as if they had just received notification that the patient would be admitted to their team. Residents were instructed to make a plan that they would verbally sign out to the oncoming resident (whose role was played by session moderators), as if the admission would arrive shortly after shift change. After signing out, a debrief session was held for the resident team as a group led by 1 to 3 session moderators.

In this simulated case of an infant with hyperbilirubinemia, exploration in the EHR beyond the ED note revealed safety probes,[9] including vital sign instability suggestive of neonatal sepsis and evidence of hemolytic anemia. During the debrief session, we emphasized the utility of specific data visualization and information retrieval activities in the EHR to detect these safety probes. The data visualization tool consisted of vital sign trends displayed graphically with the ability to overlay the timing of medication administrations, lab values, and nursing observations. The information retrieval tool was a search bar allowing the user to enter a phrase and find all instances of that phrase or related concepts in notes, labs, orders, and problem lists. These tools were chosen based on informal discussions with local clinical informaticians and patient safety experts who felt based on clinical experience that increased use of these tools might improve trainees' efficiency and ability to detect safety concerns. However, no empiric evaluation was performed to assess their impact on provider or patient outcomes. Both tools were part of native functionality in Epic Systems© versions 2014 and 2015 and had been introduced to all pediatric residents during their EHR orientation just prior to the start of their first year.

Simulations were conducted in a training environment that refreshed every night from a master training environment where the original simulated patient was built. Each refresh created 10 copies, such that each simulation participant worked on his/her own patient, and an unused patient was used for the debrief session.

EHR use patterns

We examined the association between simulation and the use of data visualization and information retrieval activities emphasized during the debrief session. As of July 1, 2015, every click on these activities in the production environment at Children's Hospital of Philadelphia was logged with the associated username, timestamp, and activity chosen. We combined these data with resident scheduling data to determine the number of clicks per week from each resident while on an inpatient service at our main hospital. All full-time categorical pediatric residents who began residency in 2014 (second- and third-year pediatric residents during the study period, never exposed to simulation), 2015 (first- and second-year pediatric residents during the study period), and 2016 (first-year pediatric residents during the study period) were included. Residents who were employed on alternative schedules (preliminary year only, fast-tracked, combined residency program, month-on month-off, or switched residencies) were excluded from this analysis. Shortened weeks in which the resident did not remain on his/her primary service due to vacation, holidays, or cross-coverage were also excluded.

Protection of human subjects

The Institutional Review Board at Children's Hospital of Philadelphia made the determination that this study did not constitute human subjects research, as it focused on quality improvement in educational activities.

Statistical analysis

We analyzed the association of simulation on the probability that a resident used specific data visualization and information retrieval tools in the EHR in a given week using mixed effects logistic regression[20] with the resident as a random effect in all models. Variables with odds ratio significantly different from 1 ($P < .05$) in univariate analysis for use of both the data visualization and information retrieval tool were initially included in the multivariable model. Colinear variables with weaker association in univariate analysis were removed from the final multivariable model. Additionally, among simulation participants, we performed interrupted time-series analysis using segmented regression to determine the immediate and long-term association of simulation exposure on use of both the data visualization tool and information retrieval tool in the EHR. All analyses were performed in R version 3.3.3.[21]

RESULTS

We followed a cohort of 139 pediatric residents from July 2015 through February 2017. A total of 57 pediatric interns participated in an EHR simulation at a median of 21 (IQR: 10-31) weeks into their residency. Our sample (Table 1) included 2650 resident-weeks among the control group, 612 resident-weeks among the intervention group prior to exposure to simulation (pre-simulation), and 1049 resident-weeks after simulation exposure (post-simulation). The median unexposed (control and pre-simulation) resident-week had been preceded by 26 (IQR 10-49) inpatient weeks and 29 (IQR 13-50) total weeks of residency. The post-simulation weeks had been preceded by a similar number of inpatient weeks (median 22, IQR 15-33, $P = .09$) but more total residency weeks (median 41, IQR 26-64, $P < .0001$).

Residents used the data visualization tool at least once in 47% of pre-exposure weeks and 73% of post-exposure weeks ($P < .0001$). Likewise, they used the information retrieval tool at least once in 36% of pre-exposure weeks and 85% of post-exposure weeks ($P < .0001$). In univariate analysis (Table 2), exposure to simulation was significantly associated with use of the data visualization tool (OR = 5.83, 95% CI: 4.38–7.84) and the information retrieval tool (OR = 10.47, 95% CI: 7.49–14.75). Among the other covariates, completed inpatient weeks were the strongest predictor of use of the data visualization tool (OR = 1.07 for each completed week, 95% CI: 1.06-1.08) and the information retrieval tool (OR = 1.10 for each completed week, 95% CI: 1.09-1.12). Of note, as residents completed a median of 28 weeks per year of residency, the contribution of completed inpatient weeks was estimated at 6.07 (95% CI: 4.83-7.69) for each completed year of residency for the data visualization tool and 15.22 (95% CI: 10.94-21.44) for the information retrieval tool. All variables collinear with the number of completed inpatient weeks including number of residency weeks, training level, and year of residency start were removed from the multivariate model.

Table 1. Characteristics of resident-weeks by prior exposure to simulation

	Control (N = 82 residents)	Intervention (N = 57 residents)	
	No. (%) of non-participant weeks (N = 2650)	No. (%) of pre-simulation weeks (N = 612)	No. (%) of post-simulation weeks (N = 1049)
Training level			
PL-1	926 (35)	612 (100)	640 (61)
PL-2	1379 (52)	0 (0)	409 (39)
PL-3	345 (13)	0 (0)	0 (0)
Year of residency start			
2014	1355 (51)	0 (0)	0 (0)
2015	958 (36)	363 (59)	675 (64)
2016	337 (13)	249 (41)	374 (36)

PL: Pediatric level – refers to the number of years of pediatrics residency the resident will have completed at the end of the current academic year.

In multivariable analysis accounting for the number of completed inpatient weeks (Table 3), exposure to simulation remained a significant predictor of data visualization tool use at least once per week (2.84, 95% CI: 2.06-3.93) and information retrieval tool use at least once per week (3.00, 95% CI: 2.02-4.51). In sensitivity analysis, the odds of using the data visualization tool and information retrieval tool at least 5 times in a given week was 2.66 (95% CI: 1.85-3.86) and 6.17 (95% CI: 4.40-8.67) fold higher, respectively, among the post-exposure weeks after adjustment. Similarly, the odds ratio after exposure to simulation of using these tools at least 10 times in a given week was 3.29 (95% CI: 2.08-5.31) for the data visualization tool and 4.78 (3.45-6.64) for the information retrieval tool.

In interrupted time-series analysis, use of the data visualization tool at least once per week increased from 43% to 64% (absolute change 21%, 95% CI: 8%-35%) immediately after simulation (Figure 1). Additionally, the slope increased from -0.21 to 0.36 (absolute change +0.57, 95% CI: +0.11 - +1.04), indicating that higher utilization was maintained over time. Use of the information retrieval tool also increased from 68% just before simulation to 80% just after simulation (absolute change 12%, 95% CI: 2%-23%) (Figure 2). While the slope decreased from 0.94 to 0.23 (absolute change -0.71, 95% CI: -1.07 - -0.36), the slope remained positive with utilization exceeding 90% towards the end of follow-up.

DISCUSSION

Our study demonstrated sustained adoption of EHR data visualization and information retrieval tools by pediatric residents following an EHR-based simulation session. In nearly 5 months of follow-up, simulation exposure was a significant predictor of residents' use of these tools after adjustment for inpatient experience. Use did not wane in the weeks subsequent to the simulation, suggesting sustained changes to residents' EHR use patterns after exposure to the intervention. Previous EHR simulation training programs have demonstrated participant engagement and learning.[18,22] However, to our knowledge, this study is the first to demonstrate persistent changes in EHR use during clinical practice due to an EHR simulation training program. These findings suggest that EHR simulation

Table 2. Odds ratio of using a data visualization tool and information retrieval tool in the EHR at least once during an inpatient week: univariate analysis

	Data visualization tool OR (95% CI, *P*)	Information retrieval tool OR (95% CI, *P*)
Exposed to simulation	5.83 (4.38-7.84, $P < .0001$)	10.47 (7.49-14.75, $P < .0001$)
Completed inpatient weeks	1.07 (1.06-1.08, $P < .0001$)	1.10 (1.09-1.12, $P < .0001$)
Previous residency weeks	1.03 (1.03-1.04, $P < .0001$)	1.05 (1.05-1.06, $P < .0001$)
Training level	2.70 (2.22-3.31, $P < .0001$)	4.97 (3.73-6.70, $P < .0001$)
Year of residency start	1.34 (0.88-2.03, $P = .17$)	6.50 (3.05-16.20, $P < .0001$)

Table 3. Odds ratio of using a data visualization tool and information retrieval tool in the EHR during an inpatient week: multivariable results and sensitivity analysis

	Data visualization tool OR (95% CI, *P*)	Information retrieval tool OR (95% CI, *P*)
Threshold ≥ 1 use per week		
Exposed to simulation	2.84 (2.06 -3.93, $P < .0001$)	3.00 (2.02-4.51, $P < .0001$)
Completed inpatient weeks	1.05 (1.04-1.06, $P < .0001$)	1.08 (1.07-1.09, $P < .0001$)
Threshold ≥ 5 uses per week		
Exposed to simulation	2.66 (1.85-3.86, $P < .0001$)	6.17 (4.40-8.67, $P < .0001$)
Completed inpatient weeks	1.05 (1.04-1.06, $P < .0001$)	1.01 (1.00-1.02, $P = .19$)
Threshold ≥ 10 use per week		
Exposed to simulation	3.29 (2.08-5.31, $P < .0001$)	4.78 (3.45-6.64, $P < .0001$)
Completed inpatient weeks	1.05 (1.04-1.06, $P < .0001$)	0.99 (0.98-1.00, $P = .02$)

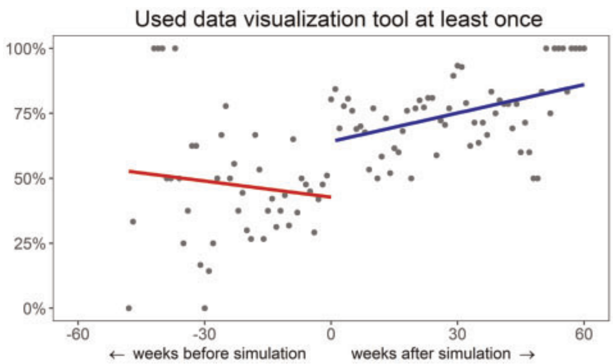

Figure 1. Interrupted time-series of data visualization tool utilization by weeks before and after simulation exposure.

Intercept of line just before simulation:	42.74% (32.26−53.21)	$P < .0001$
Slope of line before simulation:	−0.21% per week (−0.61−0.20)	$P = .31$
Change in intercept of line after simulation:	+21.42% (7.61−35.23)	$P = .003$
Change in slope of line after simulation:	+0.57% per week (0.11−1.04)	$P = .017$

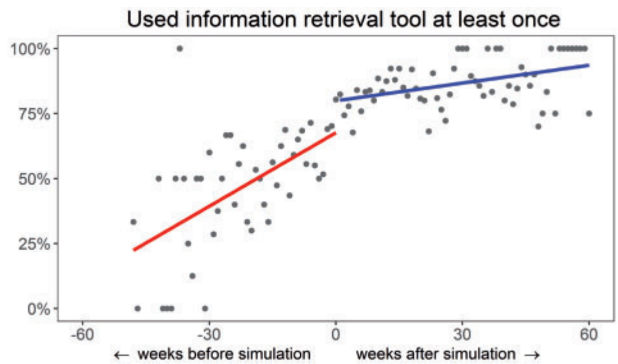

Figure 2. Interrupted time-series of information retrieval tool utilization by weeks before and after simulation exposure.

Intercept of line just before simulation:	67.62% (59.62−75.62)	$P < .0001$
Slope of line before simulation:	0.94% per week (0.63−1.25)	$P < .0001$
Change in intercept of line after simulation:	+12.28% (1.74−22.83)	$P = .023$
Change in slope of line after simulation:	−0.71% per week (−1.07 − −0.36)	$P < .0001$

can drive residents' EHR screen selection, which has been previously associated with recognition of patient safety concerns.[8]

We observed different use patterns over time for the data visualization and information retrieval tools despite the association of simulation with increased utilization of both tools in multivariate analysis. Use of the data visualization tool was low initially, but increased dramatically after simulation exposure. In contrast, use of the information retrieval tool was increasing steadily over time prior to simulation and jumped slightly only immediately after simulation exposure before leveling off. This difference may be due to different accessibility of the tools. The information retrieval tool is on the home screen by default, whereas the data visualization tool must be explicitly added to the users' activity menu. Alternatively, residents early in their training care for fewer acute patients and may have less need for the data visualization tool, whereas the information retrieval tool may provide greater efficiency gains at an early stage. The needs of residents early in their training may also be met to a minimum standard with other data visualization techniques, limiting their search for a different approach until it is introduced to them through simulation. Additionally, year of residency start was strongly associated with use of the information retrieval tool, but not with the data visualization tool in univariate analysis. Diffusion of EHR use patterns may be stronger within the same cohort of residents who started together. The time-series pattern of the information retrieval tool and its association with residency cohort suggest it may have diffused more easily between residents without as much additional training compared to the data visualization tool. Previous studies have demonstrated variability in use of new tools in the EHR over time relative to implementation;[23,24] however, the behavior changes resulting from different training methods and the subsequent diffusion patterns of the activities that were taught remain poorly understood.

To facilitate translation of EHR simulation learning to clinical practice, Mohan et al have proposed a framework for intelligent EHR simulation, which advocates for replicating real-world clinical conditions and cognitive load.[3] Many simulation platforms developed specifically for medical education present static, reformatted, simplified health records that do not imitate the look and feel of the actual EHR[2] or do not contain sufficient narrative information generally found in notes.[25] By contrast, our simulation used a training environment virtually identical to the EHR in use at our hospital, similar to programs developed for medical students.[26] We also present a common clinical scenario, highly relevant and plausible to our learners. This approach aims to maximize the *germane load*, the demand for resources devoted to learning the task (using the EHR to detect patient safety probes) rather than *extraneous load* in which the learner must use mental resources for tasks unrelated to the learning objectives, such as adapting to a new environment or adjusting to an unrealistic scenario.[10] Similarly, simulation provides the opportunity for temporally adjacent feedback immediately after the participant has completed the simulated task. Following principles of cognitive load theory in designing the simulation may have contributed to the long-term use pattern changes observed.

Our study has several important limitations. Our simulation curriculum was administered to trainees in a single residency program at one institution with a single case. Learners with different skills or EHR experience may not have benefited in the same way. Additionally, we do not compare alternative educational modalities such as lectures, observations, or one-on-one training sessions. One-on-one training sessions have demonstrated improved self-efficacy ratings among clinicians and reduced "pajama-time" documentation, but these programs may be more resource intensive and less easily scaled up than EHR simulation.[27,28] In contrast, building EHR simulations requires substantially greater resources than writing a lecture or having learners observe experienced EHR users. Our study does not determine if simulation is the most efficient educational approach, or if the simulation merely prompted discovery of different EHR tools that were later found to be useful. Finally, while this simulation may have promoted use of specific EHR tools, it is not yet known if this increased use is associated with improvements in provider efficiency or detection of safety concerns in either simulated or real clinical settings.

CONCLUSION

Our simulation is representative of the evolution in EHR training from instruction on EHR navigation toward active learning of advanced tools to facilitate complex decision making. Though a variety of platforms have been used for EHR simulation in medical student education,[2,29–32] these efforts focus on providing an initial exposure to the EHR, teaching basic EHR tasks and functions, and as a vehicle for case-based teaching of clinical concepts rather than focusing on applying tools to help integrate and organize complex clinical data. Future research will be necessary to determine if this approach yields similar results in other populations such as medical students, more senior clinicians, or residents at other institutions. More importantly, to justify scaling up investment in EHR simulation, future medical education research must demonstrate not only changed behavior but improved patient outcomes.

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CONTRIBUTORS

EWO, IRR, MVM, ACD, AL, JP, RT, and CPB contributed to the study design.
EWO, IRR, MVM, ACD, WP, and LU developed the intervention.
EWO, IRR, MVM, ACD, AL, RT, and CPB wrote the manuscript.
EWO performed the statistical analysis.

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