Investigating the Impact of Intensive Care Unit Interruptions on Patient Safety Events and Electronic Health Records Use: An Observational Study

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Background: Constant interruptions and continual data flow result in information overload for clinicians and become barriers to identification and extraction of relevant patient data and its correct interpretation. The aim of the study was to describe the types, frequencies, and impact of intensive care unit (ICU) interruptions on patient safety event occurrences and electronic health records (EHR) use.

Methods: We conducted a live observational study for 6 weeks, observing critical care physicians' and other providers' communication while recording interruptions, patient safety events, and EHR use.

Results: Across 55 hours, the researchers observed 7515 ICU tasks, 15.7% of which were interrupted. We found that technological interruptions directly influences the occurrence of patient safety events: an increase in technological interruptions directly contributes to patient safety event occurrence ($P = 0.004$). Technological interruptions had a direct effect on human interruptions, as the frequency of technological interruptions increase, human interruptions also increase ($P = 0.02$).

Conclusions: A prospective, observational study was conducted to understand the relationship between interruptions and patient safety events and EHR use, in a time-sensitive, activity-based study in a large academic medical center with a certified EHR system. We found that technological interruptions were statistically correlated to the occurrence of patient safety events, and human interruptions significantly affected the level of EHR use. This study recommends that ICUs adopt a safety culture that promotes minimizing unnecessary interruptions, such as side conversations during rounds, for improved quality of care.

Key Words: EHR, interruptions, patient safety, ICU

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Constant interruptions and continual data flow results in information overload for clinicians and become barriers to identification and extraction of relevant patient data and its correct interpretation. Technologies enable continuous patient monitoring; however, the extensive additional data have contributed to interruptions in an environment, specifically intensive care units (ICUs), characterized by significant risk. Intensive care unit (ICU) providers typically address more than 200 variables during critical care rounds.[1]

Although technologies monitoring critically ill patients generate a median of 1348 individual data points per day,[2] providers have an average of only 2 minutes to gather relevant data, synthesize it, make a decision, and act on it.[3] The overload of data leads to failure in information processing and misinterpretation of data, which can lead to sentinel events.[4] Failure in information processing is attributed directly to cognitive errors, which lead to misdiagnosis.[5] Despite attempts by investigators to determine underlying factors behind information processing failures,[6–10] the role of interruptions and electronic health records (EHR) use in clinical communication remains poorly understood. Consistent with our previous work, our team defines clinical communication as the exchange of ideas, messages, or knowledge between two or more entities through verbal, nonverbal, written, and visual forms, where entities can be individuals or technological components.[11]

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Interruptions are Common in Technology-Driven Settings

An interruption is an interference causing a pause or an end to an on-going conversation, which lengthens time on task, increases anxiety and stress, and leads to adverse events.[12–15] Interruptions may cause a provider to forget items in working memory, resulting in errors and incomplete tasks.[16,17] In aviation and nuclear power industries, interruptions were the leading cause for significant task errors[18,19]; however, in healthcare, in-depth understanding remains elusive regarding types, frequency, and implications of interruptions in the clinical setting.[18,20]

In this research, we define *human interruptions* as those in which a provide/team member asks question or interrupts an on-going clinical conversation or if team members engage in a side conversation. We define *external interruptions* as those questions or statements from nonclinicians (e.g., a patient's family member) during an on-going clinical conversation. We define *technological interruptions* as those in which pagers and patient monitoring devices (e.g., intravenous therapy pump, alarms, loose electrocardiogram leads) interfere with an on-going clinical conversation causing a communicator to pause or end the conversation. For purposes of this study, *patient safety events* are mistakes or slips occurring during bed rounds and are captured or corrected by the attending physician or another team member. Finally, we use the term *EHR use* to refer to each time the attending physician interacted with the certified EHR system either for information retrieval or storage using a mouse and keyboard.

OBJECTIVE

The purpose of this study was to describe the types, frequencies, and impact of ICU interruptions on patient safety event occurrences and EHR use. We report on the nature of interruptions in the ICU by characterizing them in two categories: human and technological interruptions.

METHODS AND MATERIALS

Study Design

We conducted a live observational study for 6 weeks, observing critical care physicians' and other providers' communication, and

TABLE 1. Clinical Communication Categories Used in the ICU Instrument

Communication Categories	Specific Details	Measurement Type
Human interruptions	• Type of questions • Side conversations • Nonclinical team personnel	Frequency
Technology interruptions	• Computer alerts • Pager • Cell phones	Frequency
EHR use	• Read-only • Interaction	Count (information/ x-ray) Count (mouse/ keyboard)
Patient safety events	• Attending physician self-correct • Team member correct attending physician	Frequency

recorded interruptions and EHR use. Two graduate biomedical informatics students observed the ICU teams during patient bedside rounds, using an observational study checklist we created for data collection.

Participants and Setting

We conducted the study at a large, tertiary Midwestern academic medical center. We observed ICU providers from 22 different clinical roles but specifically focused on attending physicians. We observed ICU clinical teams across several types of ICUs (e.g., burn, cardiac, surgical, pulmonary). At the time of the study, all settings used the Cerner EHR system (Kansas City, MO) to deliver care; providers' use of the EHR varied by their roles. We informed participants of the noninvasive nature of the study, its objectives, and duration. We obtained verbal consent from attending physicians for access to the ICUs by researchers and to shadow the team during rounds. Institutional review board approval was obtained for this study.

Procedure

The research team included the chief physician of pulmonary and critical care, two additional physicians, one patient safety expert, and three biomedical informatics and computer science researchers. The ICU team included, but was not limited to, an attending physician ("attending"), fellow, resident, respiratory therapist, registered nurse, physician assistant, and Nurse Practitioner. The primary focus of this study was the attending physician. By shadowing the attending, we captured most team communication trends and patterns because the attending was the nexus of most communication events.

Our goal was to shadow three to five attending physicians across 6 to 10 weeks. Each attending was observed six times during their 2-week rotation in the ICU. To increase the reach of this research, we distributed the observations as follows: (*a*) first day of the first week; (*b*) 2 days on a weekend; (*c*) 2 week days; and (*d*) the last day of the second week. The choice of observation days was informed by ICU domain experts and by our research biostatistician. Specifically, the first and last day of the 2-week rotations would capture the communication patterns during what is typically a more chaotic first day and then a more organized communication pattern at the end of the rotation period. In addition, weekends provided a different pace and intensity than weekdays. Statistically, by considering physicians as a treatment and repeating the observation of the same attending during different day, we would increase both the reach of the research and the validity of the data.

Measurement

The research team developed a data collection checklist tool based on literature and domain expert feedback.[21–23] During the observation session, two researchers shadowed the clinical team through bedside rounds; the researchers used the tailored ICU checklist to capture communication instances of the attending.[24,25] The researchers noted certain items at each observation, including team size, date, and time of day, among others. During each patient visit, the researchers were in the patient room with the clinical team; their aim was to monitor and record certain communication events. We designed the instrument to capture four main communication categories and included specific details and measurement type (Table 1).

Outcomes

The primary outcomes were human and technological interruptions, patient safety events, and EHR use. Human interruptions were classified as "related to topic/patient" and "unrelated to topic/patient." Only events that occurred or interrupted during an on-going conversation with the attending physician were included in this study.

Statistical Analysis

Although each attending physician was observed for 6 days, variation occurred in the number of patients visited, which suggests that the mean number of patient visits is a better measure than attending physician. For some variables, there are differences in mean value between the attending physicians, for that reason we conducted a χ^2 test to identify which variables differed significantly among the physicians. We used a 95% confidence interval, such that for a variable to be significantly different, α has to be less than or equal to 0.05 (5%). We used Pearson's correlation to determine the level of dependency among the observation variables, such as interruptions, patient safety events, and EHR use. This correlation is calculated by dividing the covariance of the two variables by the product of their standard deviations. SPSS statistical software (Armonk, NY) was used to analyze the data.

RESULTS

Across 55 hours, the researchers observed 7515 ICU tasks, 15.7% of which were interrupted. A total of 167 ICU providers were observed during 279 unique patient visits across 6 weeks. Providers were interrupted an average of four times per patient visit and 65 times during patient rounds on a given day.

Human Interruptions

Of 1186 total observed interruptions, 844 (71.1%) were human interruptions by providers, 447 (56%) were side conversations by

TABLE 2. Human Interruptions by Type, Mean per Patient Visit, and Total

Human Interruption Type	Mean (SD) per Patient Visit	Total
Side conversations	26.5 (12)	477 (56.5%)
Related questions	15.8 (6.8)	284 (33.7%)
External interruptions	3.7 (3.9)	67 (7.9%)
Unrelated questions	0.9 (1.0)	16 (1.9%)
Total	46.9	844

TABLE 3. Technology Interruptions by Type, Mean per Patient Visit, and Total

Technology Interruption Type	Mean (SD) per Patient Visit	Total
Computer alerts	11.8 (11.4)	212 (62%)
Phone	4.1 (2.1)	74 (21.6%)
Pagers	3.1 (2.4)	56 (16.4%)
Total	19	342

clinical team members, 284 (33%) were questions related to the ongoing conversation, 67 (8%) were interruptions from patients' family members, and 16 (2%) were questions irrelevant to the ongoing conversation. Table 2 contains details of human interruptions.

Technology Interruptions

Technological devices caused 324 (29%) of the 1186 total observed interruptions. Computer-generated alerts caused 212 (62%) interruptions, 74 (21.6%) were interruptions caused by cell phones, and 56 (16.4%) were pager alerts. Table 3 contains details of technology interruptions.

Relationships Among Interruptions, Patient Safety Events, and EHR Usability

Regarding the relationship between interruptions, EHR use, and patient safety events, we found that technological interruptions directly influenced the occurrence of patient safety events: an increase in technological interruptions directly contributes to patient safety event occurrence (P = 0.004), shown in Table 4. Technological interruptions had a direct positive effect on human interruptions; as the frequency of technological interruptions increased, human interruptions also increased (P = 0.02). Human interruptions had a direct negative effect on EHR use such that as human interruption decreases, EHR use increases during a patient visit (P = 0.01).

In aggregate, during bedside rounds, 342 (19%) were technology interruptions, 844 (47%) were human interruptions, 318 (18%) were EHR use, and 24 (1%) were patient safety events (Fig. 1). Human interruptions occurred more than technological interruptions by 40% during a complete patient round.

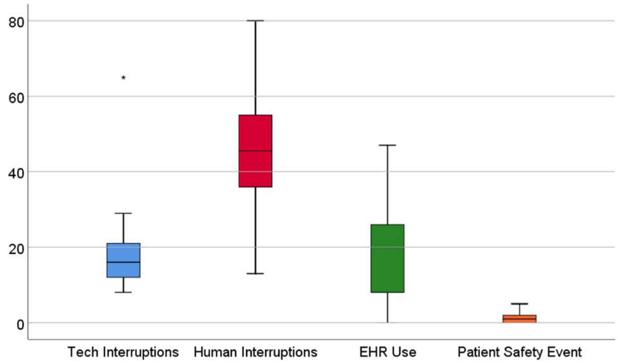

FIGURE 1. Level of prevalence of interruptions, EHR use, and patient safety events per patient rounds.

Patient Safety Events Analysis Based on Days and Team Size

The large standard deviations in communication events during rounds suggested high variability in communication. In an attempt to understand the rationale for such variability, we analyzed communication by team size and days of the week as potential confounders. The occurrence of interruptions, EHR use, and patient safety events varied depending on the size of the clinical team. We categorized team sizes as either large (≥10 persons) or small (<10). Teams in bedside rounds typically consisted of one attending physician, one fellow, two or more residents, one or more registered nurses, two or more medical students, a pharmacist, and a nutritionist. The largest team size consisted of 18 team members, and the smallest team had five members. Of 279 observed patient visits, 154 visits had small teams and 125 had large teams.

Small teams had more technological interruptions per day of rounds (mean [SD] = 21 [15.5]) than large teams (mean [SD] = 16 [7]); large teams had more human interruptions (mean [SD] = 55.6 [10]) than small teams (mean [SD] = 41 [20]) (Fig. 2). Small teams had more EHR use (mean [SD] = 22 [12]) than large teams (mean [SD] = 10 [10]), and small teams had more patient safety events (mean [SD] = 1.6 [1.5]) than large teams (mean [SD] = 0.8 [1]). When running Pearson χ^2 test of dependency, there were no significant associations. Results from testing for mean differences are shown in Table 5.

We analyzed patient safety events as to when they occurred (weekday or weekends) (Fig. 3). Patient safety events by attending

TABLE 4. Correlation of Interruptions, EHR Use, and Patient Safety Events During a Patient Round

		Human Interruptions	Tech Interruptions	EHR Use	Patient Safety Events
Human interruptions	Pearson correlation	1.0	0.534*	−0.574	0.287
	Sig. (two-tailed)		0.022	0.013	0.248
Tech interruptions	Pearson correlation		1.0	−0.396	0.642†
	Sig. (two-tailed)			0.104	0.004
EHR use	Pearson correlation	−0.574*	−0.396	1.0	−0.148
	Sig. (two-tailed)	0.013	0.104		0.558
Patient safety events	Pearson correlation	0.287	0.642†	−0.148	1.0
	Sig. (two-tailed)	0.248	0.004	0.558	

*Correlation is significant at the 0.05 level (two-tailed).

†Correlation is significant at the 0.01 level (two-tailed).

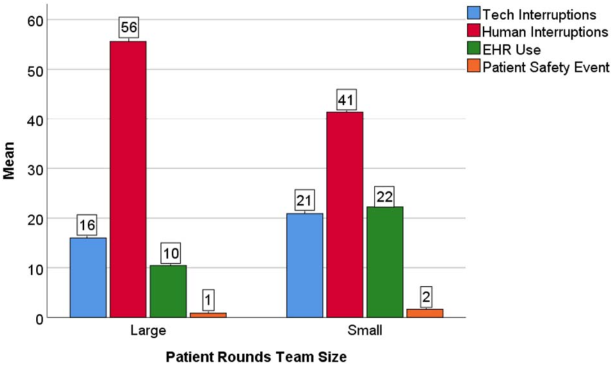

FIGURE 2. Differences between team sizes in technology and human interruptions, EHR use, and patient safety events based on team size.

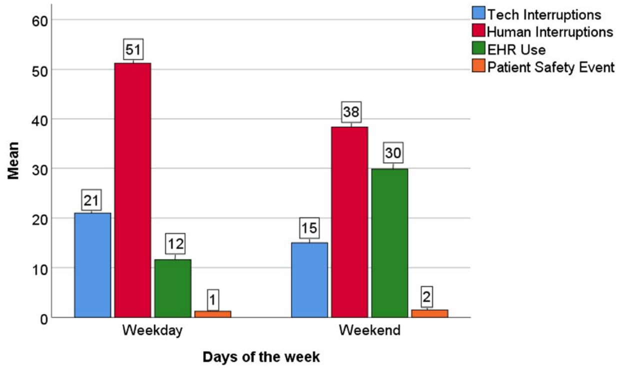

FIGURE 3. Mean of patient safety events per shift on weekdays and weekends.

physicians were higher on weekends (mean [SD] = 0.33 [0.5]) than weekdays (mean [SD] = 0.17 [0.4]), and errors stemmed by team members where higher on weekends (mean [SD] = 1.2 [1.2]) than weekdays (mean [SD] = 1.1 [1.3]). Moreover, patient safety events by team members were five times higher than those of attending physicians (Fig. 4).

DISCUSSION

In this live observational study of interruptions during bedside rounds, we explored the relationships among type of interruptions (human and technological) on EHR use and the occurrence of patient safety events, which we defined as mistakes or slips occurring during bedside rounds and which are captured or corrected by the attending physician or another team member. Across 7515 ICU events, computer-generated alerts and provider-led side conversations were the most common interruptions. Technological interruptions were correlated positively to patient safety events, such that more errors were made by team members after a technological interruption. Human interruptions were correlated negatively with EHR use, suggesting that there was less tendency for team members to interrupt when the EHR was being accessed.

Interruptions are known to contribute to procedural failures and clinical errors.[26–28] In an ICU-based observational study by Sasangohar et al,[29] they recorded 1007 interruptions, of which 43% were by clinical staff (human interruptions) and 16.42% were by technological equipment. Conversely, in a recent observational study, Johnson et al[26] reported a mean (SD) of 2.13 (1.21) interruptions per patient visit, 3.4% of which were human interruptions and 12.7% were technology interruptions. By comparison, in our study using a more comprehensive approach, we reported that of the 1186 observed interruptions, 71.2% were caused by the clinical team (human) and 28.8% were caused by technological devices, which is higher than in previously reported studies.

Furthermore, in a study investigating the relationship between interruptions and errors, Westbrook et al[30] reported that each interruption was associated with 21.1% increase in procedural failures and a 12.7% increase in clinical errors; however, Westbrook et al[30] vaguely defined interruptions as situations in which the provider paused in medication preparation or administration to attend an external stimulus. In our study, we defined interruptions concisely, categorizing them as technology-driven and human-lead interruptions and measured the relationship of each on the occurrence of visible patient safety events during the patient visit. Technology-driven interruptions, although occurring 2.5 times less often than human interruptions, were found significantly and positively related to the occurrence of patient safety events ($P = 0.04$).

Although some interruptions may seem useful superficially (i.e., urgent reminders or corrections), we argue that many interruptions may be harmful even when they are intended to be helpful. The potential danger of an interruption is not in the interruption itself, but its consequence. When a conversation is paused, the ability for the communicators to resume the same thread of conversation may be compromised. Clinical questions and family inquiries are always encouraged after an on-going conversation ends. For that reason, we argue that all types of interruptions may pose a threat to effective communication and, therefore, to patient safety.

To the best of our knowledge, there are no reported outcomes on the association of interruptions on EHR use. We sought to determine whether there is a relationship between interruptions (both human and technological) and providers' use of EHR. We are reporting that there was significant negative association between interruptions and EHR use, such that for every three human interruptions, providers used the EHR one fewer time; conversely, every one technological interruption was followed by one less use of the EHR by providers.

Future Direction and Limitations

Findings from our study are constrained by the limited number of attending physicians in the ICU. Although this study was

TABLE 5. Test for Means Differences in Technology and Human Interruptions, EHR Use, and Patient Safety Events Between Team Sizes

Team Size		Technological Interruptions	Human Interruptions	EHR Use	Patient Safety Events
Large (n = 7)	Mean (SD)	16.00 (7.02)	55.57 (9.86)	10.43 (9.96)	0.86 (1.07)
Small (n = 11)	Mean (SD)	20.91 (15.57)	41.36 (20)	22.27 (12.35)	1.64 (1.57)
Total (n = 18)	Mean (SD)	19.00 (12.89)	46.89 (17.90)	17.67 (12.65)	1.33 (1.41)

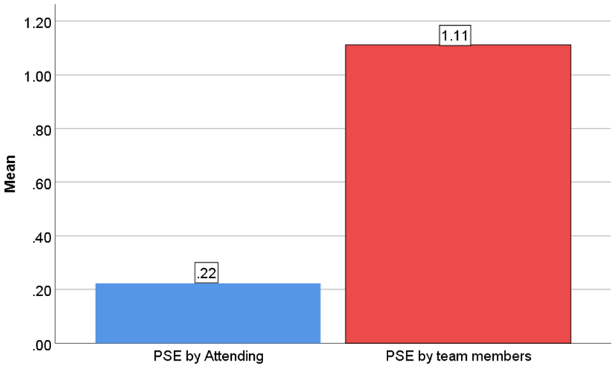

FIGURE 4. Comparison of mean patient safety events by attending physicians and team member per shift.

conducted at a 300-bed hospital with 68 ICU beds,[31] we were challenged by rotation schedules to find a larger number attending physicians to shadow during ICU bed rounds. The study focused on attending physician solely, observing other roles such as residents or nurses, may provide more insight. Furthermore, this study was limited to bed rounds and other areas of incomplete communication such as hand offs were not studied. Although the observers were noninvasive, the presence of observers may have impacted team dynamics and communication.

One strength of this study is that the ICU clinical team conducted patient rounds in multiple ICUs (e.g., burn, cardiac, surgical, and pulmonary). We did not investigate the relationship between various ICUs and communication patterns merely because the team members remained the same during a given patient rounds. Capturing instances of communication from different ICU settings, each of which has its own form of operation, could enhance our external validity across ICU specialties. In future research, we will include a multisite study, the goal of which will be to identify key factors such as information overload affecting patient safety and EHR use.

CONCLUSIONS

In a time-sensitive, activity-based study in a large academic medical center with a certified EHR system, the occurrence of patient safety events was significantly influenced by technology-generated interruptions, and EHR use was significantly affected by the number of provider-based interruptions. Knowledge of the relationships of interruptions on patient safety and EHR use may help inform a new safety culture in which unnecessary interruptions are eliminated.

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