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Exploring the Relationship between EHR Usability and Medication Dose Errors

Dasantila Sherifi 1, Isaac Olorunisola[1*], Farah Kattab[1]

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ABSTRACT

Medication dose errors (MDEs) continue to be a problem of significant patient safety concern even with the extensive adoption of Electronic Health Records (EHRs). The current literature tends to focus on the study of the underlying factors of EHR usability individually, with little knowledge of how the combination of EHR design and system characteristics affect medication dose error. This paper fills this gap by assessing the perceptions of clinicians on the connection between EHR interface design, system responsiveness, user training, alert fatigue, the efficiency of navigation, the integration of clinical decision support system (CDSS), and EHR customizability and perceived MDEs. A quantitative methodology was used in data gathering through questionnaire of 386 health care professionals and crunching the data on the basis of Pearson correlation coefficients. It was observed to have strong positive relations between perceived medication dose errors and system responsiveness, design, and EHR customizability with moderate relations with navigation efficiency and user training. There was a lesser, though significant relationship with alert fatigue. The results emphasize the significance of the optimization of the EHR performance, design, and customization of CDSSS to minimize the incidence of medication dose error and improve patient safety.

INTRODUCTION

Electronic Health Records (EHRs) have revolutionized the healthcare field by improving the documentation of patient care and sharing data with other health providers to facilitate better patient care coordination (Cahill *et al.,* 2025). While these advantages are realized, the usability of EHR remains a critical problem, especially in medication management. Ease of use means the degree to which healthcare providers can navigate, input, retrieve, and interpret information within an EHR system (Park *et al.,* 2024). It is known that poor usability has caused medical errors, particularly medication dose errors, due to the complexity of interfaces, alert fatigue, data entry errors, and workflow mismatches (Pruitt *et al.,* 2023). Medication Dose Errors (MDE), whether because of wrong prescription, order, dispensing, or administration can lead to adverse patient events, extended hospital stay, higher healthcare expenses, and even death. As healthcare systems rely increasingly on digital documentation and communication, there is a need for investigation into the relationship between EHR usability and medication dose errors.

Transition from paper-based care records to digital EHR systems intended to significantly reduce medication errors through automated alerts, clinical decision support systems (CDSS), and standard documentation (Azmi *et al.,* 2023). However, research shows that improperly designed EHR interfaces and workflow disruptions may lead to new types of mistakes, including the incorrect dosing of a medication. Design flaws leading to usability issues may raise the risk of medication dose errors. Incorrect data entry and errors in patient information can also occur due to poor user interface, cognitive overload, and poor navigation complexity (Adeyemi *et al.,* 2024). Although much has been written about medication errors, there is a gap in the literature related to how EHR usability contributes to dose-related mistakes (Madandola *et al.,* 2024). Research on medication errors focuses mostly on prescribing patterns and clinical decision support mechanisms. Furthermore, reported MDEs are much lower than the actual MDEs (Abdalla *et al.,* 2020), which brings up the importance of measuring the likelihood of MDEs through clinicians' perceptions. Understanding the potential relationships between EHR usability and MDE can help healthcare providers and system designers better understand the risks associated with poorly designed EHR interfaces (Adams *et al.,* 2021) and possibly lead to improvements.

Despite the growing EHR adoption and EHR usability issues, the relationship between EHR usability and MDE has not been addressed well enough, and it is critical to address this problem to enhance system design, improve clinical workflow, and improve patient safety (Murthi *et al.,* 2024). This study investigates EHR usability challenges and MDE from the perspective of providers engaged in medication administration activities.

LITERATURE REVIEW

Effect of Design Features on Usability of the Interface

The layout of an EHR interface makes it easier or more difficult for healthcare workers to use the system, interface, and navigate workflows like medication procedures. Dose calculation tools, dropdown menus,

[1] Rutgers University, United States
[*] Corresponding author's e-mail: isolacs@gmail.com

and order form structures lead to medication dose errors (Kush *et al.* 2020; Ratwani *et al.* 2018). Time constraints and situational pressure contribute to gaps in medication oversight, leading to the selection of wrong drug, strength, or dose (Roberts, 2022). The consequences can be severe (Lloyd *et al.,* 2021). It is well known that order-centric designs do not fit physicians' clinical workflows (Li *et al.* 2019), which explains why clinicians triage orders with automatic steering. User-centered designs address these flaws by integrating expectations, increasing workflow, and reducing human error. Lindén-Lahti *et al.* (2022) argue that physicians perceive current EHRs as exhausting because they click endless buttons, leading to template rigidity, which hinders the practice of safe mediating or enabling switching to safe medication practices. Design features are directly related to the usability of the interface.

Responsiveness Affects Clinical Decision Making

The speed and dependability of an EHR system, or system responsiveness varies. System lags interfere with workflow, placing time pressure on clinicians, which potentially induces hasty and incorrect dosing choices (Ratwani *et al.,* 2018). Some lags when accessing patients' data or ordering them into different systems emerge during emergencies, which creates potential for critical mistakes in such situations. Furthermore, continuous lags can cause the clinician to bypass verification sequences, selections of appropriate medications, and neglect contraindications. Such usability barriers heighten the cognitive demands placed on healthcare experts, increasing the chances of operating in stressful conditions (Roberts, 2022). On the other hand, a responsive EHR facilitates the immediate and quick prescribing of medications by having instantaneous access to necessary information. Carayon *et al.* (2018) confirmed that, in the empirics, practitioners are most affected by slowness of the system and poorly designed interfaces that do not allow for safe prescribing. Therefore, enhancing system performance is not only an issue of system design, but a matter of safety. Providing effortless and speedy EHR functions helps eliminate some of the MDEs, especially in critical situations.

User Training Enhances Safe EHR Use

User training and user experience significantly impact the safe and effective application of EHR systems. Pruitt *et al.* (2023) argue that increased exposure to EHRs improves effectiveness and may lead to fewer medication errors. However, this experience may have unintended consequences. For example, once accustomed to the system, healthcare providers may become over-reliant on defaults or unmindful of alerts, leading to complacency. Roberts (2022) also discusses this phenomenon, explaining that critical safety features are assumed to be bypassed by seasoned users. Additionally, informal methods of quick completion, often developed by clinicians, tend to leave out important checks and safety measures. According to Singhal *et al.* (2023), even more experienced users tend to misinterpret alerts, omit critical verification steps, or fail to validate recommendations made by the EHR. Stated otherwise, ongoing training is needed on an interface's safety features to minimize misuse of the system and enhance interface changes. Such education, when systematic and periodic, reduces human error and ensures the safe medication administration through the EHR.

The Impact of Over-Notifications on Cognitive Load

Excessive alerting can hinder the safe use of medication on EHRs and Dial Systems. Clinical Decision Support Systems (CDSS) integrated in EHRs provide medication alerts, but CDSS systems, unfortunately, tend to issue excessive, repetitive, and irrelevant alerts (Samal *et al.,* 2023). Such information overload makes it almost impossible for clinicians to do more than dismiss or override critical alerts, lowering the chances of MDEs (Grossman *et al.,* 2019). An overwhelming number of alerts disrupts workflows, increases cognitive load and may result in clinicians ignoring true positives. Alert fatigue contributes to missing critical thresholds to overrate alerts, leading to dosage miscalculations (Poly *et al.,* 2020; Yu *et al.,* 2019). Flexible interruptive alert systems guarantee minimum disruption while maximizing relevance. Systems should be designed to provide alerts that are sensitive to context and relevant to clinical practice, seamlessly integrating into workflow. This is important for reducing clinicians' risk of distraction and reducing error during medication management.

Navigation Hurdles Restrict the Efficient Use of Resources

Poorly designed EHR system navigation can impede efficient clinical decision-making while raising the risk of medication errors. Navigation issues often result from fragmented workflows, excessive documentation procedures, and inconsistent screen layouts. These vexing elements impede accurate data input or retrieval (Bergin *et al.,* 2019). Such barriers to usability require nurses and clinicians to spend undue mental effort to access clinical information, detracting them from patient care. Carayon *et al.* (2018) also noted that the violation of the navigational logic increases prescribing errors due to oversights or faulty decisions. Medication order delays or inaccuracies stem from the lack of cohesion between clinical workflows and practice. Lindén-Lahti *et al.* (2022) pointed out how perplexing system designs compromise safe medication workflows, increasing the likelihood of MDEs. Clear and logically configured routing instructions adapted to healthcare routines are vital. Such navigational routes mitigate mental barriers, avert errors, and enhance provider satisfaction with EHR systems.

Clinical Decision Support System Design and Its Impact on Safety Outcomes

The integration of a CDSS with the EHR system

appears to be the strongest influence on its effectiveness. Reduction in medication errors can be achieved through proactive CDSS features such as alerts, dosing recommendations, and contraindication notifications (Samal *et al.,* 2023). On the contrary, improper alignment with clinical workflows or excessive non-contextual alerts can handicap the system. In their studies, Grossman *et al.* (2019) and Barisoni *et al.* (2020) reported that automation bias due to CDSS features coupled with alert fatigue results in over-reliance on incorrect dose acceptance and dismissal of alerts, thereby elevating the chance of MDEs. Roberts (2022) explains that delayed response in CDSS results from poor interface design, contributing to cognitive overload. SBAR integration of CDSS tools requires that they be unobtrusive and tailored to the specific situation and built in conjunction with the end users. Clinically relevant and actionable alerts are fundamental for minimizing errors. Adhering to these criteria improves the safety of care driven by EHR.

Customization and System User Fit

Usability with EHR systems and safe medication practices are highly dependent on customizability. Templates that are rigid and non-customizable are often termed useless by clinicians as they do not cater to specific workflows or personal preferences (Roberts, 2022). Such rigidity forces providers to follow customized, inefficient templates that increase the chances of mishaps, errors, and discrepancies in medication ordering or administration. Lack of flexibility within EHR systems is a source of cognitive fatigue and monumental error-prone tasks (Lindén-Lahti *et al.,* 2022). Possessing customization options such as default order sets, shortcut creation, or tailored interface layouts enhances task accuracy and efficiency. These findings support customizable EHRs significantly increase user satisfaction, decrease time spent navigating, and lower the risk for MDEs (Singhal *et al.,* 2023). Customized EHR settings based on user roles and specialties enhance the safety and effectiveness of medication management practices.

Medication Dose Errors

Even though the literature is rich in discussing issues related to the usability of EHR systems, very little attention has been paid to MDEs because of EHR design (Poly et al, 2020). Most studies attribute medication errors to usability problems, but very few attempt to partition errors into categories, for example, dosage errors (a sub-category of medication errors). This lack of focus inhibits advancement in targeted design modification. According to Clarke and Ghersi (2022), the boundaries of the systems interoperability gap result in communication failures culminating in the misinterpretation of dosing instructions. The foregoing leads to the conclusion that healthcare practitioners overlook reporting gaps resulting from EHR design, leading to design underreporting. Understanding the design implications in the medicating process of dosing requires greater precision. More design-focused studies and user engagement strategies need to be conducted to establish how EHRs become a risk factor in patient safety.

Based on the review, we hypothesize that clinicians' responses will show the following:

H1: Three is a positive correlation between EHR interface design and MDEs.

H2: There is a positive correlation between system responsiveness and MDEs.

H3: There is a positive correlation between user training and MDEs.

H4: There is a positive correlation between alert fatigue and MDEs.

H5: There is a positive correlation between system navigation and MDEs.

H6: There is a positive correlation between CDSS design and MDEs.

H7: There is a positive correlation between EHR customizability and MDEs.

MATERIALS AND METHODS

A quantitative approach was used to measure practitioner's level of agreement with the EHR interface design, system responsiveness, integration with a clinical decision support system (CDSS), healthcare provider experience, and MDE occurrence. This method is necessary when seeking to address widespread technological impact in clinical settings (Chali *et al.,* 2022).

A structured questionnaire was created based on the literature review findings, directly related to the 8 categories discussed above. A framework is shown in Figure 1. For each category, there were 3 related statements used to collect data on participants' perception of different aspects of EHRs and their relationship with medication dose safety. A structured questionnaire helps with consistent, reliable and comparable responses, which allows subjective perceptions to be quantified into measurable data that can be analyzed statistically (Bihu, 2021). The questionnaire included 24 statements pertaining to the EHR interface design, system responsiveness, CDSS integration, healthcare provider experience, and MDEs, which are congruent with the findings identified in the literature review. Participants responded by selecting their level of agreement with the statements from a five-point Likert scale, from strongly disagree to strongly agree, to allow for uniform and quantifiable data like elsewhere. The following are 3 examples of the statements:

- EHR interface is intuitive and can be navigated easily.
- Frequent alerts reduce attention to critical ones.
- EHR system may contribute to medication dose errors, depending on the design.

The questionnaire was electronically distributed among various hospitals and clinics in the US east coast area seeking healthcare professionals engaged in medication administration activities, such as physicians, physician assistants, nurses, nurse practitioners, and pharmacists. They are the primary users of EHR systems for clinical responsibilities, and the most important end users in medication management, contributing to the most relevant experiences and perceptions of EHRs and their

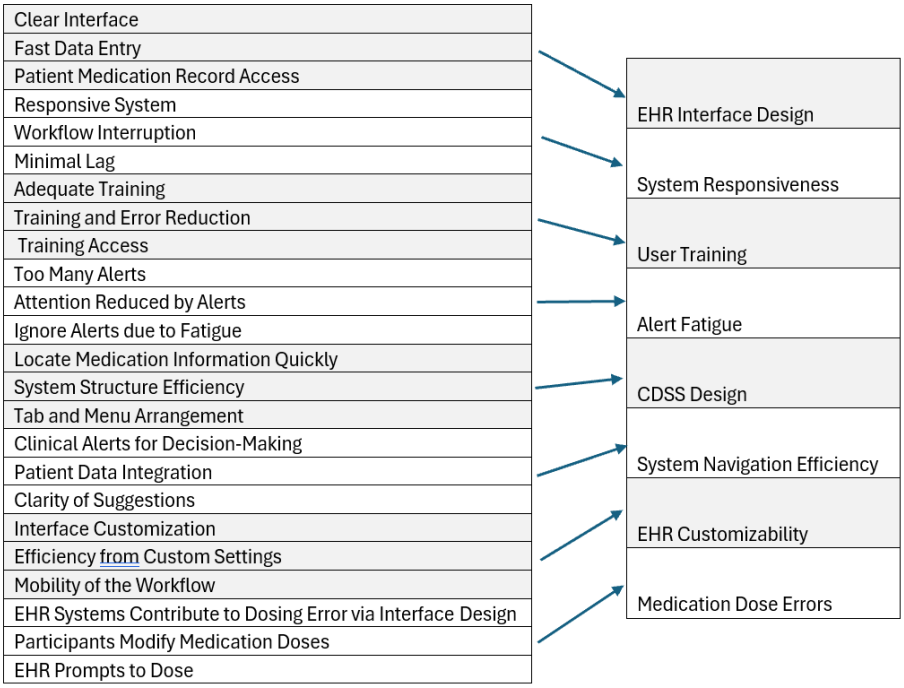

Figure 1: Conceptual Framework for EHR Usability and Medication Dose Errors

relationship to MDEs. IRB approval was obtained from the relevant institutional review boards, and informed consent was provided to participants before starting the questionnaire.

Statistical Package for the Social Sciences (SPSS) was used to code the Likert Scale responses and analyse the data. SPSS provides comprehensive data management and statistical analysis capabilities, ensuring accurate, reliable, and valid results to support the research objectives (Taherdoost, 2022).

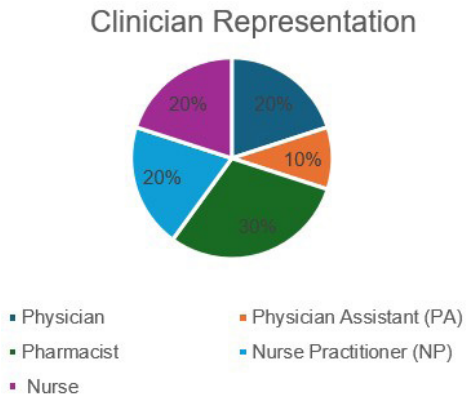

Figure 2: Clinician Representation

Figure 3: Years of Experience

RESULTS AND DISCUSSION

Results

Demographics

Surveys were completed by 386 respondents working in medication administration capacities, in healthcare organizations located in the US east coast. The sample size is statistically adequate, and it is reasonable that this sample size would include enough diversity to account for variance in EHR within various healthcare settings (Jobst *et al.,* 2023). The sample size was composed of physician (20%), physician assistants (10%), pharmacists (30%), registered nurses (20%) and nurse practitioners (20%) (Fig.2). Level of experience within the sample varied from less than one year to more than 10 years of experience. Figure 3 shows distribution by years of experience.

In addition to the years of experience, participants were asked about the frequency of using an EHR for medication prescription and administration. Only 20% responded that they always use an EHR, 30% use an EHR often, 10% use an EHR sometimes, and 20% rarely use EHR, and 20% never use an EHR for medication management.

Table 1: Frequency Analysis

N#	Statement	Frequency 1	Frequency 2	Frequency 3	Frequency 4	Frequency 5	Total	Mean
1	Clear Interface	50 (13.0%)	16 (4.1%)	16 (4.1%)	81 (21.0%)	223 (57.8%)	386	4.55
2	Fast Data Entry	33 (8.5%)	17 (4.4%)	16 (4.1%)	88 (22.8%)	232 (60.1%)	386	4.40
3	Patient Medication Record Access	33 (8.5%)	17 (4.4%)	16 (4.1%)	88 (22.8%)	232 (60.1%)	386	4.40
4	Responsive System	33 (8.5%)	17 (4.4%)	16 (4.1%)	88 (22.8%)	232 (60.1%)	386	4.40
5	Workflow Interruption	50 (13.0%)	16 (4.1%)	16 (4.1%)	81 (21.0%)	223 (57.8%)	386	4.40
6	Minimal Lag	33 (8.5%)	17 (4.4%)	16 (4.1%)	88 (22.8%)	232 (60.1%)	386	4.40
7	Adequate Training	33 (8.5%)	17 (4.4%)	16 (4.1%)	88 (22.8%)	232 (60.1%)	386	4.40
8	Training and Error Reduction	50 (13.0%)	16 (4.1%)	16 (4.1%)	81 (21.0%)	223 (57.8%)	386	4.40
9	Training Access	19 (4.9%)	10 (2.6%)	26 (6.7%)	14 (3.6%)	317 (82.1%)	386	4.40
10	Too Many Alerts	33 (8.5%)	17 (4.4%)	16 (4.1%)	88 (22.8%)	232 (60.1%)	386	4.40
11	Attention Reduced by Alerts	15 (3.9%)	19 (4.9%)	19 (4.9%)	66 (17.1%)	267 (69.2%)	386	4.40
12	Ignore Alerts due to Fatigue	50 (13.0%)	16 (4.1%)	16 (4.1%)	81 (21.0%)	223 (57.8%)	386	4.40
13	Locate Medication Information Quickly	33 (8.5%)	17 (4.4%)	16 (4.1%)	88 (22.8%)	232 (60.1%)	386	4.40
14	System Structure Efficiency	19 (4.9%)	10 (2.6%)	26 (6.7%)	14 (3.6%)	317 (82.1%)	386	4.40
15	Tab and Menu Arrangement	50 (13.0%)	16 (4.1%)	16 (4.1%)	81 (21.0%)	223 (57.8%)	386	4.40
16	Clinical Alerts for Decision-Making	15 (3.9%)	19 (4.9%)	19 (4.9%)	66 (17.1%)	267 (69.2%)	386	4.40
17	Patient Data Integration	50 (13.0%)	16 (4.1%)	16 (4.1%)	81 (21.0%)	223 (57.8%)	386	4.40
18	Clarity of Suggestions	19 (4.9%)	10 (2.6%)	26 (6.7%)	14 (3.6%)	317 (82.1%)	386	4.40
19	Interface Customization	50 (13.0%)	16 (4.1%)	16 (4.1%)	81 (21.0%)	223 (57.8%)	386	4.40
20	Efficiency from Custom Settings	19 (4.9%)	10 (2.6%)	26 (6.7%)	14 (3.6%)	317 (82.1%)	386	4.40
21	Mobility of the Workflow	15 (3.9%)	19 (4.9%)	19 (4.9%)	66 (17.1%)	267 (69.2%)	386	4.40

22	EHR Systems Contribute to Dosing Error via Interface Design	50 (13.0%)	16 (4.1%)	16 (4.1%)	81 (21.0%)	223 (57.8%)	386	4.40
23	Participants Modify Medication Doses	50 (13.0%)	16 (4.1%)	16 (4.1%)	81 (21.0%)	223 (57.8%)	386	4.40
24	EHR Prompts to Dose	15 (3.9%)	19 (4.9%)	19 (4.9%)	66 (17.1%)	267 (69.2%)	386	4.40

Frequency Analysis

Respondents reviewed the 24 statements, and for each of them, selected one of the five ratings between strongly asked and strongly disagree. A summary of the responses for each statement is presented in Table 1.

Clear Interface

The EHR interface is primarily regarded as visually clear and easy to navigate. 57.8% of respondents rated the interface at the highest level (5), and 21% rated it as 4. This means that nearly 79% of users consider the interface user-friendly. In contrast, only 13% strongly disagreed, suggesting that the system design effectively supports decision-making with clarity and ease of use.

Support for Quick Data Entry

The screen layout of the EHR system facilitates efficient data entry, as reflected by an overwhelming 82.9% of respondents who gave positive ratings (4 or 5). Of these, 60.1% provided the maximum score (5), indicating a strong endorsement of the layout's ability to streamline medication data entry processes. Only 8.5% strongly disagreed while a small percentage (8.6%) offered neutral or mixed feedback. These results emphasize the critical role of an optimized layout in supporting accuracy and speed in high-pressure environments like healthcare.

Patient Medication Record Access

The system also performs well in enabling users to locate patient medication records quickly. 82.9% of respondents provided positive ratings (4 or 5) and a small portion (8.5%) strongly disagreed, indicating room for improvement. Overall, these findings demonstrate that the system's navigation tools effectively support users in finding critical patient information with minimal effort.

Responsive System

Most users (60.1%) selected the option that strongly agrees with the claims regarding the effectiveness of the Electronic Health Record (EHR) system in responding to their actions. In addition, 22.8% rated the responsiveness as 4, which means that about 83% of users seem to like the system's speed. About 17% rated system responsiveness as 3 or lower implying some dissatisfaction.

Workflow Interruption

When presented with the statement of workflow is not interrupted by delays in EHR systems, 78.8% of users strongly agreed or agreed, and 17.1% disagreed or strongly disagreed.

Minimal Lag

Most users (60.1%) strongly agree that they experience little to no system lag during medication orders, while another 21% agree moderately. About 13% strongly disagreed or disagreed, indicating some respondents have more frequent system lag issues. These results highlight that performance is relatively stable during essential tasks such as medication ordering.

Adequate Training

The majority, about 83% of respondents agreed or strongly agreed that they were adequately trained regarding the EHR's use in medication ordering. On the other hand, almost 13% of respondents disagreed or strongly disagreed, asserting that additional training may have been necessary.

Training and Error Reduction

When presented with the statement that the training provided impacted error reduction, almost 79% strongly agreed or agreed. These findings are consistent with the prior response on overall EHR training, which highlights the importance of clinicians' adequate EHR training in promoting patient safety. Disagreement was noted by about 17% of respondents, who do not believe that level of training is related to errors.

Training Access

Regarding the availability of refresher training, over 85% strongly agreed or agreed, which means they continue to have access to trainings. However, 7.5% strongly disagreed or disagreed, which indicates some barriers to ongoing training and learning opportunities for clinicians.

Too Many Alerts

Most respondents (82.9%) reported receiving too many alerts during medication entry. With such high volume, the user may experience alert fatigue, becoming desensitized to the information presented. About 13% disagreed or strongly disagreed with receiving too many alerts, during medication entry. In most cases, it seems that the system appears to be overloaded with alerts.

Attention Reduced by Alerts

Most respondents (86.3%) strongly agree or agree that frequent alerts reduce their attention to critical ones.

This means that with increased frequency of alerts, users become less attentive to the most important information, thus putting patient safety at risk. Only about 4% of respondents believed that alerts did not reduce attention.

Ignoring Alerts due to Fatigue

When asked about ignoring alerts due to fatigue, almost 79% selected agree or strongly agree, and about 17% selected disagree or strongly disagree.

Information on Medications and Their Associated Data

About 83% agreed or strongly agreed that they can locate medication information and any associated data quickly. On the contrary, about 13% reported being unable to access such information efficiently, which can be a demonstration of design issues and lack of training.

System Structure Efficiency

When presented with a statement that the EHR system is structured to support task completion efficiently, over 85% of respondents agreed or strongly agreed that it does. Only 7% disagreed or strongly disagreed.

Tab and Menu Arrangement

About 79% of respondents agreed or strongly agreed that tab and menu arrangement is satisfactory; in other words, they mostly don't have any concerns about the layout. About 17%, however, disagree or strongly disagree, which shows the variability in the EHR screen layout.

Clinical Alerts for Decision-Making

Along the lines of clinical decision support, 86.3% of respondents agreed or strongly agreed that clinical alerts are helpful for decision making. About 9% disagreed or strongly disagreed.

Patient Data Integration

About 79% of respondents agree or strongly agree that the system integrates pertinent patient data with the process of medication prescribing, hence addressing the possibility of mitigating errors such as allergies, interactions, or contraindications. Over 17% disagree or strongly disagree, which means that flaws in patient data integration still exist.

Clarity of Suggestions

Over 85% of users reported that suggestions offered by the system are within their comprehension and are easy to apply. On the other side, 7.5% disagreed or strongly disagreed, an indication that the EHR generated prompts and suggestions are not clear in all cases.

Interface Customisation

When asked about interface customization, almost 79% of respondents strongly agreed or agreed that their EHR systems can be customized to fit their needs. About 17% disagreed or strongly disagreed.

Efficiency from Custom Settings

When presented with the statement that efficiencies may be gained from custom settings, 85.6% agreed or strongly agreed. Consistently with prior statements, 7.5 % or respondents disagreed or strongly disagreed.

Mobility of the Workflow

Over 86% of respondents agreed or strongly agreed that the EHR enhances mobility of the workflow. This indicates that EHRs enable most clinicians to manage roles, documentation, medication prescribing, and follow-up activities, from various locations. About 10% disagreed or strongly disagreed.

EHR Systems Contribute to Dosing Error via Interface Design

When presented with the statement that EHR systems contribute to medication dose errors via interface design, about 79% of the respondents strongly agreed or agreed, while about 17% disagreed or strongly disagreed.

Participants Modify Medication Doses Given System Defaults

A interesting finding is that almost 79% of participants report modifying medication doses in the EHR system given the system defaults. This is known as 'corrective dose prescribing' and it often requires manual overriding. A little over 17% disagreed or strongly disagreed with the statement.

EHR Prompts Related to Medication Dose

Over 86% of respondents responded that the EHR prompts for changing medication dosage and responds to the clinician action. On the other side, almost 9% disagreed or strongly disagreed with the statement.

Neutrals

It should be noted that a consistent 4% of respondents chose the neutral option, which could mean lack of knowledge when it comes to EHR design and use or lack of engagement in the process.

Categorical Analysis

Guided by the literature review, statements were grouped into 8 categories for further analysis. For example, statements about clarity of interface, data entry and patient medication record access were grouped into the

Table 2: Categorical Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
EHR Interface Design	386	1	5	4.55	1.063
System Responsiveness	386	1.000	5.000	4.235	.7627
User Training	386	1.000	5.000	4.164	.9821

Alert Fatigue	386	1.000	5.000	4.398	.6814
System Navigation Efficiency	386	1.000	5.000	4.27	.7573
CDSS Design	386	1.333	5.000	4.348	.694
EHR Customizability	386	1.333	5.000	4.348	.694
Medication Dose Errors	386	1.000	5.000	4.185	1.00
Valid N (listwise)	386				

category of 'EHR Interface design'. Also, statements related to receiving adequate training, training impacts error reduction, and access to training, were grouped into 'user training category'. Table 1 shows highlighted rows for every 3 statements, which are linked in order to the 8 categories shown in Table 2.

The summary descriptive statistics suggest that users generally, express positive experience in relation to the EHR Interface design, system Responsiveness, system navigation efficiency, CDSS, and ability to customize the EHR settings but there is a consistent minority that reports otherwise. Users also report a favorable view towards EHR training and perceive it as an important factor that may contribute to MDEs. In regard to alerts, majority report an overload, impact on attention, and even ignoring the alerts.

Correlations

Pearson correlation analysis among the categories is shown in Table 3. Hypothesis testing is shown in table 4.

Table 3: Correlations

		EHR Interface Design	System Responsiveness	User Training	Alert Fatigue	System Navigation Efficiency	Clinical Decision Support Integration	EHR Customizability	Medication Dose Errors
EHR Interface Design	Pearson Correlation	1	.047	.063	.543**	.522**	.531**	.531**	.034
	Sig. (2-tailed)		.361	.216	.000	.000	.000	.000	.506
	N	386	386	386	386	386	386	386	386
System Responsiveness	Pearson Correlation	.047	1	.857**	.690**	.782**	.738**	.738**	.803**
	Sig. (2-tailed)	.361		.000	.000	.000	.000	.000	.000
	N	386	386	386	386	386	386	386	386
User Training	Pearson Correlation	.063	.857**	1	.623**	.844**	.447**	.447**	.539**
	Sig. (2-tailed)	.216	.000		.000	.000	.000	.000	.000
	N	386	386	386	386	386	386	386	386
Alert Fatigue	Pearson Correlation	.543**	.690**	.623**	1	.683**	.622**	.622**	.277**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.000
	N	386	386	386	386	386	386	386	386
System Navigation Efficiency	Pearson Correlation	.522**	.782**	.844**	.683**	1	.755**	.755**	.653**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.000
	N	386	386	386	386	386	386	386	386
CDSS Design	Pearson Correlation	.531**	.738**	.447**	.622**	.755**	1	1.000**	.832**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000
	N	386	386	386	386	386	386	386	386
EHR Customizability	Pearson Correlation	.531**	.738**	.447**	.622**	.755**	1.000**	1	.832**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.000
	N	386	386	386	386	386	386	386	386
Medication Dose Errors	Pearson Correlation	.034	.803**	.539**	.277**	.653**	.832**	.832**	1
	Sig. (2-tailed)	.506	.000	.000	.000	.000	.000	.000	
	N	386	386	386	386	386	386	386	386

***. Correlation is significant at the 0.01 level (2-tailed)*

Table 4: Hypothesis Testing

Hypothesis	Pearson Correlation (r)	Sig. (2-tailed)	Decision (α = 0.01)	Interpretation
H1: Three is a positive correlation between EHR interface design and MDEs.	0.034	0.506	Rejected	No significant relationship
H2: There is a positive correlation between system responsiveness and MDEs.	0.803	0.000	Accepted	Strong positive significant relationship
H3: There is a positive correlation between user training and MDEs.	0.539	0.000	Accepted	Moderate positive significant relationship
H4: There is a positive correlation between alert fatigue and MDEs.	0.277	0.000	Accepted	Weak to moderately significant relationship
H5: There is a positive correlation between system navigation and MDEs.	0.653	0.000	Accepted	Strong positive significant relationship
H6: There is a positive correlation between CDSS design and MDEs.	0.832	0.000	Accepted	Very strong, positive, significant relationship
H7: There is a positive correlation between EHR customizability and MDEs.	0.832	0.000	Accepted	Very strong, positive, significant relationship

Discussion

These results are an indication of how clinicians perceive the EHRs, their usability, features, and most importantly, some of their reactions to them, and how they may contribute to medication dose errors. Findings are consistent with prior academic literature, as well as the direct observations of the first author of this study, in his capacity as a practicing health informatician. As reported by clinicians engaged in medication management activities, when EHRs don't respond and function well, and lack integration of well-designed CDSS, medication dose errors also happen. Level of training seems to be a very important element, as well.

Additional analyses show a positive correlation between Alert Fatigue and Clinical Decision Support System Integration (CDSSI). The parameter estimate of 0.110 (P = 0.014) represents the association between increased alert fatigue and a higher degree of integration in the CDSS (Yu *et al.,* 2019). This may indicate that the closer clinicians are to the alerts, the more prominent the CDSS integration in their perception. However, it may cause alert fatigue and the rejection of important warnings. Nevertheless, the lack of strong influence of Alert Fatigue on Perception of Medication Dosage Errors (p > 0.05) indicates that alert fatigue exists but is not necessarily associated with higher medication errors. If so, this would suggest that other players offered in the system, such as system design and user experience, may be even more influential regarding medication safety.

A significant relation (P = 0.053) exists between the paths from Alert Fatigue to User Training. This means that training programs tailored to helping professionals manage alert fatigue well may be helpful, focusing on the most pertinent alerts and improving how they manage alerts within the EHR systems.

CDSS and EHRS Interface Design are also positively correlated (P = 0.000), with a parameter estimate of 0.872. Based on this, effective integration of CDSS leads to more functional and intuitive interfaces in EHR systems. Better user experiences with the EHR system can also result from the improved integration of well-designed decision support system into the EHR system, and this can be used to allow faster and more accurate decision making. Secondarily, represented by the path from CDSS to Perception of Medication Dosage Errors (P = 0.056), it can show that though using decision support systems integration is important, they may not be the sole enabler of reduction in medication dosing errors. Additionally, this might imply that the alerts and recommendations issued by CDSS are not entirely used or that the system design does not adequately deal with the underlying factors of medication errors.

Interestingly, there is an insignificant path from Healthcare Provider Experience to User Training (P = 0.483), although with a high parameter estimate of 4.251. Common sense assumes that when one has experience with EHR systems, one gets used to them and becomes sufficient on their own, so they do not see the need for training. However, this lack of substantive effect points out a general problem in presenting people on the EHR solely with what is familiar, possibly generating complacency and lowering vigilance in using the EHR in such a method, which might improve the chance of harmful medication errors.

Additionally, the path from System Navigation Experience to EHR Usability (P = 0.319) is not significant, thus suggesting that a more efficient and easier path to navigate with an EHR system will not necessarily mean a more usable EHR system. Thus, although system navigation generally influences usability, other factors such as interface design and system functionality significantly influence user experience and medication safety.

The results show that the focus of improving EHR systems to obtain better medication safety should be optimizing the alert system, enhancing the system's responsiveness, and adequately integrating well-designed

decision tools. Finally, the study suggests the need for user training programs focusing on reducing the cognitive load created due to the system's complexity and alert fatigue, facilitating healthcare providers' utilization of EHR systems while avoiding the adverse effect on patient care. Such measures could have an impact on improving medication dosing errors.

Clinical experience has demonstrated that perception of medication safety is a critical matter in the identification and avoidance of medication dose errors (MDEs). Duplicate medication is a common-suggested area of potential error, but in certain instances the advantage can be worth the accompanying risk, including maintaining continuity of care or as an intentionally mitigating redundancy system. The difference between a clinically indicated duplication and an act of error is to a large part determined by the perceptual accuracy and judgment of healthcare providers. This highlights the need to encourage effective perceptual and evaluative abilities in clinicians as sensible perception of risk to medications is no less essential than technical protection in electronic health record (EHR) systems to reduce MDEs and enhance patient safety outcomes.

Future system designs should focus on developing intuitive interfaces, context-sensitive clinical decision support tools, and responsive systems to reduce cognitive workload and improve provider satisfaction. Policymakers and healthcare administrators should also prioritize training programs to equip providers with the skills to navigate EHR systems effectively.

Future research should explore longitudinal studies to evaluate the sustained impact of EHR usability improvements on medication safety. Additionally, qualitative studies capturing real-world experiences of healthcare providers can offer deeper insights into usability challenges and inform user-centered design strategies. Lastly, experimental studies testing specific design modifications, such as reducing alert fatigue in CDSI or streamlining workflows in interface design, can further validate the practical applications of these findings.

Limitations

This study has several limitations that should be acknowledged. While the sample size of 386 participants is reasonably large and diverse, it may not fully capture the breadth of healthcare professionals' experiences across varying clinical settings, limiting generalizability. The reliance on self-reported data introduces potential biases, including inaccurate recall, social desirability, and subjective interpretation of medication dose errors. Additionally, the cross-sectional design restricts the ability to infer causal relationships between EHR usability variables and perceived medication errors. Variations in EHR systems across institutions, along with potential language barriers or misinterpretations of survey questions, may have contributed to discrepancies in responses. Lastly, despite efforts to minimize non-response bias, the possibility of an unrepresentative sample remains. Future studies could address these limitations by employing longitudinal designs to track changes over time or experimental setups to establish causal links between EHR usability and medication safety. Incorporating standardized EHR systems across study sites, using objective measures of medication errors, and conducting multilingual surveys with pilot testing could further enhance the reliability and generalizability of findings.

CONCLUSION

The findings of this study highlight the critical role of EHR usability when it comes to medication dose errors. Systems that are designed well, perform and respond sufficiently and can be customized proficiently create a safer technical environment for clinicians and their likelihood of making medication dose errors. Proper training and training refreshers are also important in improving medication dose errors. The results underscore the need for a holistic approach to EHR system improvements, focusing on usability dimensions that align with clinical workflows and reduce cognitive burden to specify how these enhancements can be implemented, healthcare organizations can foster positive provider experiences and minimize medication-related errors.

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