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Title: Methods for studying medication safety following electronic health record implementation in acute care: a scoping review

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Abstract

Objective: The objective of this scoping review is to map methods used to study medication safety following electronic health record (EHR) implementation. Patterns and methodological gaps can provide insight for future research design.

Methods: We used the Joanna Briggs Institute (JBI) scoping review methodology and a custom data extraction table to summarize the following data: (1) study demographics (year, country, setting); (2) study design, study period, data sources, and measures; (3) analysis strategy; (4) identified limitations or recommendations; (5) quality appraisal; and (6) if a Safety-I or Safety-II perspective was employed.

Results: We screened 5,879 articles. One hundred and fifteen articles met our inclusion criteria and were assessed for eligibility by full-text review. Twenty-seven articles were eligible for extraction.

Discussion: We found little consistency in how medication safety following EHR implementation was studied. Three study designs, seven study settings, and ten data sources were used across 27 articles. None of the articles shared the same combination of design, data sources, study periods, and research settings. Outcome measures were neither defined nor measured consistently.

Conclusion: It may be difficult for researchers to aggregate and synthesize medication safety findings following EHR implementation research. All studies but one used a Safety-I perspective to study medication safety. We offer a conceptual model to support a more consistent approach to studying medication safety following EHR implementation.

BACKGROUND

Medication safety is both the practice and outcome of being free from preventable harm resulting from medication use (1). In acute care, *medication practice* refer to the prescription, verification, preparation/dispensing, delivery/storage, administration, documentation, and monitoring of medications (2). Upholding medication safety is a healthcare priority around the world where medication-related incidents result in avoidable morbidity and mortality and cost global healthcare systems upwards of 42 billion USD annually (3–6). Electronic health records (EHRs) have the potential to improve medication safety through applications that facilitate interdisciplinary medication-related workflows, including computerized physician order entry (CPOE), clinical decision support (CDS), pharmacy verification, barcode medication administration (BCMA), and electronic medication administration records (eMARs) (7). See Table 1 for definitions of common medication-related EHR applications.

Table 1. Common medication-related EHR applications.

Computerized Provider Order Entry (CPOE)	An application for prescribers that facilitates entering and sending treatment instructions – including medication, laboratory, and radiology orders (8).
Clinical Decision Support (CDS)	An application for prescribers that includes a variety of tools to enhance decision-making in clinical workflow, including computerized alerts and reminders to care providers and patients, clinical guidelines, and condition-specific order sets. (9).
Pharmacy Integration	An application which allows pharmacists to engage in and support documentation, medication reconciliation, and patient evaluation (10).
Barcode medication administration (BCMA)	An application that allows for electronic verification that medications are being provided to the right patient, at the right dose, at the right time, and via the right route (11).
Electronic medication administration records (eMAR)	An application that takes the place of a paper-based medication administration record. An eMAR can be used to: order and modify medication; document medication administration; verify medication orders; and access drug references (12).

SIGNIFICANCE

Interventions to enhance medication safety are often signaled when prescribing or administration errors and/or harms are identified in real-life or simulated settings (13,14). This retrospective approach to understanding and responding to improve safety can be classified as Safety-I, whereby safety is known and ‘measured’ by the absence of errors, incidents, and risks, and/or conformance to standard operating

procedures (SOPs; i.e., *work-as-imagined*) (2,15–17). Safety-I is often used as a paradigm for understanding medication safety, and safety in general. Alternatively, Safety-II and resilience engineering are newer philosophies within health systems research that aim to expound actual work practices initiated by direct care providers (i.e. *work-as-done*), and aspire to use these new learnings to drive improvements (15,17). In this study, we adopted Safety-II as a complementary paradigm with the aim of elucidating a more comprehensive insight into the examination of medication safety after the implementation of EHRs.

OBJECTIVE

To date, there are no reviews which map the methods used to study medication safety following EHR implementation. The purpose of this scoping review is to map the methods used to study medication safety in acute care settings following EHR implementation and to develop guidance for future research on this topic. Our review question is, “What methods do researchers use to study medication safety following EHR implementation in acute care settings?”.

METHODS

This scoping review was conducted in accordance with the Joanna Briggs Institute (JBI) methodology for scoping reviews (18) and in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (19). We chose a scoping review methodology to fulfill this research objective as our goal was to map the methods used to study medication safety in peer-reviewed literature versus appraise research outcomes (18,20). A preliminary search of PROSPERO, MEDLINE, the Cochrane Database of Systematic Reviews, and JBI Evidence Synthesis was conducted in January 2021 and again in March 2023, and no current or in-progress reviews that map the methods used to study medication safety were identified.

Inclusion Criteria

Population

Our population was limited to global medication safety studies that occurred in acute care settings.

Concept

We considered studies that explored the effect of EHR implementation on medication safety in terms of

practices and/or outcomes. These could include incidents or successes/efficiencies at any phase of medication delivery in acute care and/or any good outcome, near miss, or harm of any kind that reaches the patient.

Context

We included studies where authors clearly described the methods they used to study medication safety following EHR implementation. We extracted information associated to research setting, design, and analysis strategies. Studies that use modern electronic medication records (EMRs) and electronic medication management systems (EMMSs) were included as they often include the same applications as EHRs (21). We used the term EHR to refer to either EHR, EMR, or EMMSs for the remainder of the paper.

To be included, studies needed to provide evidence that more than one healthcare discipline and more than one phase of medication practice was being evaluated. This was essential to capture the complex adaptive nature of healthcare systems which may include sociotechnical complexity, and/or interoperability. We excluded simulation-based studies and pre- or post-production usability testing. We did not limit inclusion by year of publication as we anticipated that the terms EHR, EMR, and EMMS would be self-limiting to approximately the last two decades.

Types of Sources

We included peer-reviewed qualitative, quantitative, multi-methods, or mixed methods evaluations of EHRs. We also included peer-reviewed protocols, reviews, and conceptual papers with an explicit focus on methodology, or practical resources recommended by established health, quality and safety organizations.

Exclusion Criteria

To focus on the scientific methods used to study medication safety, we excluded editorials, commentaries, non-peer reviewed book chapters, conference abstracts, anecdotal accounts, discussions, or opinion papers. We also excluded studies where EHRs were used to study/measure medication safety of specific

medications as these studies did not examine the effect of the EHR on medication safety in general. See Table 2 for a full list of inclusion and exclusion criteria.

Table 2. Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Peer Reviewed	-
Qualitative, quantitative, multi-methods or mixed-methods articles, protocols, reviews, book chapters or conceptual papers	Editorials, commentaries, conference abstracts, anecdotal accounts, discussion, or opinion papers
EHR/EMR/EMMS	-
More than one EHR application, plus evidence of multiple disciplines and/or multiple parts of the med admin process studied	-
Studies that include methods for studying medication-related patient safety incidents/concerns/successes	-
Peer-reviewed articles where incidents/concerns/successes are linked to the EHR	-
Acute Care settings – Hospitals/Inpatient Units/Emergency Departments	-

Search Strategy and Information Sources

In July 2020, we developed a search strategy with a university health sciences librarian, and conducted an initial search of MEDLINE and CINAHL. We also screened titles, abstracts and index terms of relevant papers (Appendix I). In February 2021, January 2022, November 2022, and September 2023, we searched the MEDLINE, CINAHL, and EMBASE databases, which are known for their focus on the health sciences. We combed the reference lists of included articles and of those authors who specialize in medication safety research, and used Google Scholar to search for other relevant articles. We also identified popular health safety and improvement organizations' websites to search for additional literature.

Screening Procedures and Study Selection

We used Covidence Systematic Review Software (Veritas Health Innovation, Melbourne, Australia, 2020) to store retrieved titles and abstracts and delete duplicate articles. Reviewers (JD, TK, CC, and NM) pilot-screened a sample of 40 titles and abstracts per pair to calibrate agreement between reviewers. Any disagreements were resolved through discussion with the lead author (NP). Once sufficient

agreement was obtained, NP screened all articles at the title and abstract phase and JD, TK, CC, or NM completed the second screen, achieving 93% agreement. NP and JD conducted full text reviews in duplicate. See Table 3 for the list of exclusion decisions at the full-text screen phase. Any disagreements that arose between the reviewers at each stage of the screening process were resolved through discussion. The results of the search are reported in the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flow diagram in Figure 1 (22).

Table 3. Examples of exclusion and associated examples at the full-text screen phase.

Reason for Exclusion	Example
Wrong Outcomes	The article's primary objective was incident detection
Wrong Intervention	The intervention implemented was not an EHR
Wrong Topic	The primary topic was not about EHR application or medication safety
No Methods	No methods were described for how to study medication safety
Missing Study Design Elements	Unclear EHR applications related to medication workflow
Wrong Study Design	Usability study with no direct link to medication safety
Wrong Setting	Study was conducted in a Primary Care setting

Data Extraction

Data extraction was completed by two independent reviewers (NP and TH) using a customized data extraction table. Both reviewers extracted data from all articles, and discussed to reach consensus where concerns and/or discrepancies arose. Data elements extracted were: (1) study demographics (year, country, setting); (2) study design, study period, data sources, and measures; (3) analysis strategy and rationale; (4) author's identified limitations or recommendations for future studies; and, (5) whether authors employed a Safety-I or Safety-II perspective.

Quality Appraisal, Meta-Bias and Synthesis

Although quality appraisals are not required for scoping reviews (18), as this is the first review of this topic, we chose to review the quality of the included studies to better understand the literature. Two reviewers (NP and TH) used Joanna Briggs Institute Critical Appraisal Tools to appraise the quality of all included studies (23). Disagreements were discussed and resolved via consensus.

RESULTS

A total of 5,879 abstracts were identified through our literature search. We found no additional articles via reference list screening. We searched 12 health safety and improvement organizations' websites found via Google searches and by expert recommendation, but no additional literature matching our criteria was found (Appendix II). One hundred and fifteen articles passed title and abstract screening, and one hundred and eleven were assessed by full-text review. Twenty-six articles met final eligibility criteria, and data from each of these studies was extracted, mapped, and themed, as below (see Appendix III and IV for details).

Date, Location, and Setting of Publication

Twenty-one out of 27 of the articles were published from 2016 to 2022 (24–44). The earliest article was published in 2007 (45). The majority of the studies (n=10) were conducted in the United States (25–27,29,33–35,45–47) and Australia (n=10) (41,48–55), while the remaining ones were published in the United Kingdom (n=4) (28,44,56,57), Finland (n=2) (58,59), and Singapore (n=1) (60). The studies covered various acute care settings, including entire hospitals (n=16) (26,27,33,35,41,42,45,47,48,50,51,54,55,58,60,61), adult intensive care (n=4) (25,29,36,46), a surgical unit (n=2) (56,57), a medicine unit (n=1) (44), an oncology unit (n=2) (28,52), and an emergency department (n=1) (34). Additionally, two pairs of studies were conducted by the same authors using data collected from the same setting and time period (25,46,56,57).

Study Design, Data Collection Method, Data Sources and Measures, and Vendor and Release Date

Twenty-two studies employed a cross-sectional design, utilizing either pre-post evaluation (with control (n=2) (50,60); without control (n=10) (24–26,28,29,31,34,36,44,56,57)), or post-evaluation (with control (n=2) (48,54); without control (n=7) (27,47,51–53,55,59)). These studies used various study periods and collected quantitative data from different sources, including paper and/or electronic charts (n=10) (25,27,29,34,46,48,50,55,56,61), voluntary organizational incident reports (n=10) (26,28,35,47,51,52,54,55,58,60), observations (n=6) (29,33,39,44,57,61), and surveillance systems (n=1) (27). The most commonly measured outcomes were incident type and frequency (n=14) (24–

31,39,43,44,56,60,62) and harm severity/patient outcome (n=8) (25,26,28,46,52,56,58,60) (Figures 2, 3 & 4).

The EHR applications utilized in the studies included at least two of the following: CPOE, CDS, eMARs, a pharmacy verification/dispensing system, BCMA, automated dispensing, and electronic physician and/or nursing charting. The most commonly studied EHR applications included a combination of CPOE (n=20) (24–32,34,36,39,43,44,53,55–57,61,62), eMAR (n=20) (24,25,27,29,30,32,34,36,37,39,40,43,44,53,55–57,60–62), pharmacy verification/dispensing (n=10) (25,26,28,34,36,46,52,54,58,60), and BCMA (n=9) (27,29,34,36,47,48,56–58). The studies were designed to evaluate various phases of medication practice, including ordering/prescribing (n=16) (24–29,31,32,34,43,44,53,55,56,60,62), transcription (n=9) (26–28,46,52–54,58,60), dispensing (n=12) (26–29,34,46,48,52–54,58,60), preparation (n=10) (26–28,46,50,52–54,57,58), administration (n=22) (24–32,34,36,37,39,40,43,44,53,55–57,60,62), monitoring (n=8) (26–28,46,52–54,58), and documentation (n=12) (26–29,31,32,39,43,44,53,55,62).

Four studies employed a qualitative design to gain insights into the state of medication safety using the following data sources: direct observation and focus groups (n=1) (33), expert opinion (n=2) (35,45), literature review (n=1) (35), user-generated feedback (n=1) (45), and records of system updates (n=1) (41). The EHR applications utilized in these studies included at least two of the following: CPOE (n=3) (33,41,45), CDS (n=2) (41,45), eMARs (n=2) (33,41), a pharmacy verification/dispensing system (n=1) (45), and BCMA (n=1) (33). One study did not specify which EHR applications were included in the system, but instead used local data to develop a taxonomy for studying medication safety following EHR implementation (35). The outcomes measures in the other three studies included the frequency of prescribing (n=1) (33), administration errors (n=2) (33,45), time spent on medication administration (n=2) (33,45), frequency of performing patient identification (n=1) (33), frequency of observing patients taking oral medications (n=1) (33), accuracy of documentation (n=1) (33), types of system-related updates (n=1) (41), and the nature of workflow violations (n=1) (33). Out of the 26 studies, 16 included information

about the EHR system's vendor (25,26,28,29,34,35,41,45,46,50,52–58), while only five studies specified both the EHR vendor and the version or release date (25,34,46,56,57).

One study was designed using a stepped wedge randomized control trial (RCT) (49). Frequency-based analysis of data from chart reviews, observations, and interviews/focus groups were proposed for an evaluation of CPOE, CDS, and eMAR systems.

Analysis Strategies

Twenty-one out of the 22 cross sectional studies employed frequency-based analysis as a strategy to detect change (24,26,28–32,34,36,37,39,40,43,44,55–57,60,62). Four of these also themed results (26,41,43,44). The remaining three cross-sectional studies employed different approaches: one used logistic regression to correlate EHR adoption with the occurrence of adverse drug events (27), one themed survey results (53), and one conducted a sociotechnical analysis by examining charts to identify EHR-related concerns (25). Among the four qualitative studies, one generated themes from user-generated feedback and expert anecdotal opinions regarding medication safety following EHR implementation (45). Another performed and evaluated task analysis to assess and evaluate workflows (33). The third conducted iterative tests of change and consensus building to design a conceptual framework (35), and the fourth asked directly about the system to elicit feedback (41).

Limitations and Recommendations Identified by Authors

For studies that utilized voluntary incident reports as a data source, authors acknowledged that an unknown number of incidents and errors go unreported and undetected, so reported data may be under representative (26,28,47,51,52,54,58,60). When data was collected through chart reviews, it was noted that the differences in data collection from physical charts to electronic charts could potentially influence data reliability (29,55). Furthermore, some authors identified the limitation of studying one setting and one type of EHR at a specific point in time, as the findings may not be applicable to other settings (25,35,41,46).

In regard to establishing a link between identified errors and the EHR, three authors admitted the difficulty of establishing such a connection (27,35,58). For studies that relied on observations or physical

presence for data collection, two study teams acknowledged the possibility of missing incidents or events (50,57), and a few authors noted the potential influence of the Hawthorne effect (33,48–50). Other limitations highlighted by authors included the failure to collect participant demographics (33), studying an EHR system where paper-charting was still required for certain medications (29,55), no randomization (50), small sample sizes (36,59), variations in patient acuity within intervention and control groups (48), and studying only one technology despite multiple interventions being implemented (34). Notably, two studies did not identify any limitations (45,57).

In one pre-post study that utilized incident reports as data, authors proposed that incorporating observations could enhance researchers' understanding of clinical practices, emphasizing the importance of considering clinician perspectives (54). Other authors suggested linking to patient-centered outcomes could strengthen their studies (34,48). Finally, several authors recommended incorporating prospective data collection methods to capture real-time risks (28), involving multi-disciplinary teams in event reviews (55), and utilizing improved classification systems to enhance data analysis (55).

Safety-I versus a Safety-II Perspective

Twenty-six studies employed a Safety-I perspective, which involved studying and measuring medication safety by assessing errors, harms, violations, missed steps, workarounds, delays, and challenges in medication practice following EHR implementation. One study utilized both Safety-I and Safety-II perspectives to understand the effect of EHR implementation on medication safety.

Quality Appraisal

Each article was appraised against a Joanna Briggs Institute Critical Appraisal Tool (Appendix V). Out of the total, twenty-two studies utilized a cross-sectional design, while four employed a qualitative approach, and one was designed as a stepped wedge randomized control trial. Among the cross-sectional studies, eight lacked detailed descriptions of their study sites, four of those did not adequately describe the EHR exposure. This results in uncertainty regarding the adoption of specific EHR applications in comparison to other sites. One study did not report their outcomes from a study based on voluntary incident reports in a valid and reliable way. Three cross-sectional studies did not identify potential confounding factors, and

all but one study did not employ strategies to mitigate their effects. Confounding factors can distort the relationship between the exposure (EHR) and outcome (medication safety); thoughtfulness about mitigating factors can help increase the validity of findings. In the case of qualitative studies, none of them addressed important quality indicators, such as stating a philosophical perspective, clarifying the cultural or theoretical positioning of the researchers, or considering the influence of the researcher on the researched. This is important as qualitative research requires transparent positionality to increase the trustworthiness of the findings. Only one of the four qualitative studies provided evidence of ethical approval. The RCT was not truly a randomized study, decisions on which unit would receive the intervention were not concealed from participants, nor were researchers blind to the assignment of the intervention group.

DISCUSSION

Our aim was to map how medication safety has been studied following EHR implementation in acute care settings. We excluded several articles retrieved through this search due to vague descriptions of the methods used to evaluate medication safety following EHR implementation and/or ambiguous descriptions of which medication-related EHR applications were implemented.

We observed a lack of consistency in the study of medication safety following EHR implementation. Despite the utilization of three study designs, seven study settings, and ten data sources across 27 articles, none of the articles shared the same combination of design, data sources, study periods, and research settings. One-third of studies did not include details of the study setting and 15% of all studies did not include details about the EHR vendor and/or release date. Consequently, aggregating findings from EHR implementation research becomes challenging. The quality appraisal uncovered areas where authors could enhance the rigor of their study designs.

Safety-I versus Safety-II: A Resilience Mindset

In 26 out of 27 articles, authors approached their medication safety studies using a failure or deficit-based perspective known as Safety-I. Their aim was to examine medication safety by identifying incidents, errors, deviations, and failures from expected norms. We identified only one article that assessed how

multiple medication-related EHR applications interact and effect patient safety from the perspective of Safety-II (44). This article used observations to understand changes to processes in complement to their Safety-I lens on medication administration errors. To understand safety from a Safety-II perspective, one must appreciate the knowledge, attitudes, and practices used by direct care providers to achieve successful care outcomes, which was apparent in this study. This understanding of *work-as-done* may challenge desired policies and procedures and highlight the difference between *work-as-done* vs *work-as-imagined* (15).

It is easy to overlook the importance of *work-as-done* when there are no obvious red flags to draw attention to, what may appear to be, routine work. However, the Safety-II perspective encourages administrators and leaders to identify and reinforce actions that necessarily deviate from standard operating procedures to ensure patient safety. This approach allows for a resilience engineering lens, where *work-as-imagined* can systematically evolve based on flexible, creative, and contextually adaptive *work-as-done* (15,17).

Although Safety-II and resilience engineering have not been widely or formally adopted in the study of medication safety or healthcare safety, in general, solely using a Safety-I lens poses risks. When the safety profile of a program or site is determined solely by measuring failures, patient harms, or deviations from *work-as-imagined*, it may lead to an incomplete understanding of safety as a holistic phenomenon. Researchers may misconstrue the safety profile of a site if they solely rely on the Safety-I perspective. Harvesting Safety-II information and incorporating that learning into policies, procedures, guidelines and technology can enhance safety in ways that the Safety-I perspective alone cannot achieve.

Recommendations

Below are recommendations including design elements that should be considered for future studies of medication safety following EHR implementation (Figure 5).

Recommendation One: Uncover Technical and Sociotechnical Dependencies

One crucial factor to consider in EHR and medication safety research is the impact of EHR applications on work processes from both technical and sociotechnical perspectives. From a technical standpoint, it is

essential to integrate EHR applications to ensure accurate and seamless data transfer between different applications. This integration is vital for direct care providers to interpret and use data safely. The sociotechnical perspective of EHR use is equally important. Direct care providers should be able to understand, utilize, and input data in ways that support workflows, unit culture, norms, as well as the experiences of clinicians and patients (63).

As we screened articles for this review, we noticed that many authors focused on studying a single medication-related EHR application or the experiences of a specific discipline. However, studying medication-related EHR applications in isolation from other related applications and focusing on a single discipline can lead to incomplete perspectives of the context. For instance, if a program implements CPOE, CDS, eMAR, pharmacy verification, and BCMA but the evaluation only focuses on pharmacy verification-related timestamps, the reported outcome improvements may not be solely attributable to that specific change. The observed changes may be influenced by the other integrated applications that were not evaluated or described, resulting in an inaccurate representation of a changes to medication safety. The usability of modern EHRs relies on the integration of multiple embedded applications, and therefore, understanding the overall impact of EHRs on medication safety requires consideration of these embedded applications. Moreover, EHRs do not function on their own; they function within complex adaptive sociotechnical systems involving human beings. Adopting a sociotechnical perspective, such as the one presented by Sittig, et al. (64), can be beneficial in EHR and medication safety research. This model illustrates a continuous flow of information between humans and technology. For future research on EHRs and medication safety, researchers can utilize the eight interacting dimensions of the sociotechnical model to acknowledge and explore technical and sociotechnical dependencies that might otherwise be overlooked. The methods required to capture these sociotechnical dependencies are likely qualitative and experiential in addition to quantitative (44,65–67).

Recommendation Two: Provide EHR-Specific Definitions and Details

When researchers design studies to examine the influence of EHR's on medication safety, we recommend beginning by clarifying their operational lens of medication safety. Definitions play a crucial role as they

influence the data that researchers choose to capture. For instance, when studying medication errors and the associated degree of harm, researchers often rely on voluntary incident reporting systems. On the other hand, if researchers aim to understand near misses, close calls, and workflows, they may need to observe practices or engage in conversations with direct care providers.

Secondly, it is crucial to report details of: (1) the research setting, (2) the data collection periods, and (3) the EHR applications implemented, including the vendor, version, and release date. This information enables consumers of research to identify which applications are being evaluated over which time periods and in which contexts. In EHR and medication safety reviews, researchers often present medication safety conclusions as if EHR capabilities were equivalent, despite the fact that different instances of EHRs may vary significantly in terms of application integration and functionality (68). Aggregating findings from heterogeneous studies can lead to over estimation, misinterpretation, and reduced precision of overall findings.

Recommendation Three: Capture a Comprehensive Picture of Safety

We recommend utilizing multiple data sources to gain a more well-rounded perspective on medication safety. While voluntary incident report and chart review data is an important starting point for understanding the nature and distribution of incidents throughout a healthcare system, it is inaccurate to draw conclusions on patient safety solely based on these incomplete data sources (69). An important approach for future consideration is to augment incident reports and chart reviews (Safety-I) with a resilience engineering approach (Safety-II) by studying workarounds, workflows, work articulation, and knowledge, attitudes, practice, and process changes (44,65–67,70). By adopting a Safety-II and resilience engineering approach, researchers can explore the adaptive capacity and resulting solutions direct care providers employ to promote medication safety despite any challenges they may face (71). Integrating Safety-II with traditional Safety-I approaches would provide a comprehensive and complementary analysis of medication safety via a prospective and reactive comparison of policies (*work-as-imagined*) and practices (*work-as-done*). The analysis can offer valuable insights for EHR improvement teams to implement more effective system design changes (70).

Strengths and Limitations

We followed a comprehensive methodology for scoping reviews as outlined by JBI, and the PRISMA process was employed to report our findings. All studies underwent a double-blinded review during the title and abstract screening, as well as the full-text decision making phases. Two reviewers were involved in data extraction and quality appraisal. Language was not a limiting factor in this review, as we were able to review English abstracts of studies written in other languages. However, the review is limited by factors such as inadequate methodological description in some articles, which led to their exclusion from the review. Additionally, studies that did not specify the medication-related EHR applications being studied were also excluded. Consequently, important published research on this topic may have been overlooked. Furthermore, outpatient and community settings were excluded from our review, but future research could explore these settings. Lastly, since Safety-II is still an emerging concept, there are no established search terms specifically designed to retrieve research evaluated from this perspective, which means that some relevant articles may have been missed.

CONCLUSION

The literature on medication safety following EHR implementation is currently characterized by heterogeneity, making it challenging to synthesize articles that address the same topic. Furthermore, the predominant use of the Safety-I perspective by researchers may limit a comprehensive understanding of the real-world challenges and successes associated with working with EHRs. These factors have implications for the progression of the field over time.

Implications for Research

Based on the findings of this scoping review, we propose a new conceptual framework comprising important research design elements. To bring consistency to the field, we recommend the following design elements are included in subsequent studies: (a) acknowledge technical and sociotechnical dependencies; (b) provide specific definitions and details; and, (c) capture a comprehensive picture of safety. Consistent reporting of these design elements will facilitate a more meaningful aggregation of research on this topic. Finally, adopting a Safety-II and resilience engineering approach can offer

alternative methods and a complementary perspective understanding medication safety. By examining what goes right and learning from those instances, we can further enhance patient safety and prevent harm.

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Competing Interests Statement

The authors have no competing interests to declare.

Data Availability Statement

The data underlying this article are available in the article and in its online supplementary material.

Contributorship Statement

NP, RE, ACS, and PB contributed to the study design. NP, CC, NM, JD, TK, and TH refined inclusion and exclusion criteria and conducted article screening. NP and TH conducted quality appraisals, data extraction, and data interpretation. NP drafted the manuscript. All authors have read, revised, and approved this version of the manuscript and its submission to the Journal of the American Medical Informatics Association. The development of this manuscript has adhered to ethical standards of research.

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