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Review Article

Connected Healthcare System Technology Interventions to Improve Patient Safety by Reducing Medical Errors: A Systematic Review

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ABSTRACT

Medication or medical mistakes, the third highest cause of death in the United States, occur from prescription writing to administering the therapy, with serious clinical and cost repercussions. Digital health technologies, such as connected healthcare systems, have the potential to reduce pharmaceutical errors and increase patient safety. This systematic review was conducted to find literature evidence to improve patient safety and reduce medication errors with connected healthcare interventions. This systematic review was conducted using the PRISMA 2020 guidelines. PubMed, SCOPUS, EBSCO, and Google Scholar databases were searched from January 1, 2000 to June 30, 2024 using keywords: medication errors, patient safety, and connected healthcare. A qualitative narrative analysis was conducted for the review. The detailed search yielded 9524 papers in total. In the process of duplicate removal, 4856 duplicate articles were found. After the removal of duplicate articles, 4615 were found not suitable or relevant to the topic of this study and were removed. Finally, 53 articles were chosen for the review study after screening and duplication removal. Ten of the 53 articles were review articles (18.9%), and 43 (81.1%) were original. The research indicates that various connected healthcare system technologies are more effective in minimizing errors and enhancing care quality. Integrating computerized physician order entry and clinical decision support systems may further reduce medical errors. However, many areas require additional research, and the outcomes are mixed. A balanced strategy that combines innovation, practical safety, and outcome evaluation is preferable.

Keywords: medical errors, patient safety, connected healthcare system, digital health, health technology

INTRODUCTION

The connected healthcare system (CHS) has transformed healthcare by increasing health and disease management efficiency. The Institute of Medicine's publication, "To Err Is Human," emphasized patient safety, prompting more research into measurement, accreditation, and regulation. Peter Pronovost of Johns Hopkins University emphasizes the importance of healthcare safety protocols, such as increased hand washing and barcoding, in reducing hospital-acquired illnesses.[1] In 2009, Brigham and Women's Hospital deployed computerized physician order entry (CPOE) and electronic health records (EHR) technology, which resulted in a 36% reduction in adverse events and a 47% reduction in mortality.[1] Internationally, I-PASS, which represents the five components of quality patient handoff (illness severity [I], patient summary [P], action list [A], situational awareness and contingency plans [S], and synthesis by the receiver [S]) is being used to combat medical errors. Safety improvement is inextricably linked to effective management and a safety culture. The Agency for Healthcare Research and Quality (AHRQ) Health Survey 2.0 assesses safety culture in healthcare institutions, addressing 5% total occurrence of diagnostic errors per emergency department visit.[2,3] Research suggests that diagnostic errors can be reduced through enhanced cooperation, patient engagement, cognitive work, malpractice reform, clinical decision assistance, artificial intelligence (AI), and preventive initiatives. The World Health Organization (WHO) and the AHRQ prioritize increasing resources and infrastructure for outpatient safety, addressing issues such as physician stress, burnout, and culture. The AHRQ is spearheading interdisciplinary research to ensure dependable interventions and accurate reporting.[4,5] Research is critical for generating successful solutions in healthcare systems. Policymakers should set up a national knowledge clearinghouse, address safety concerns, apply best practices, and put scientific advances into practice. Regulating connected health is necessary to improve safety and efficiency.[1,4] The current

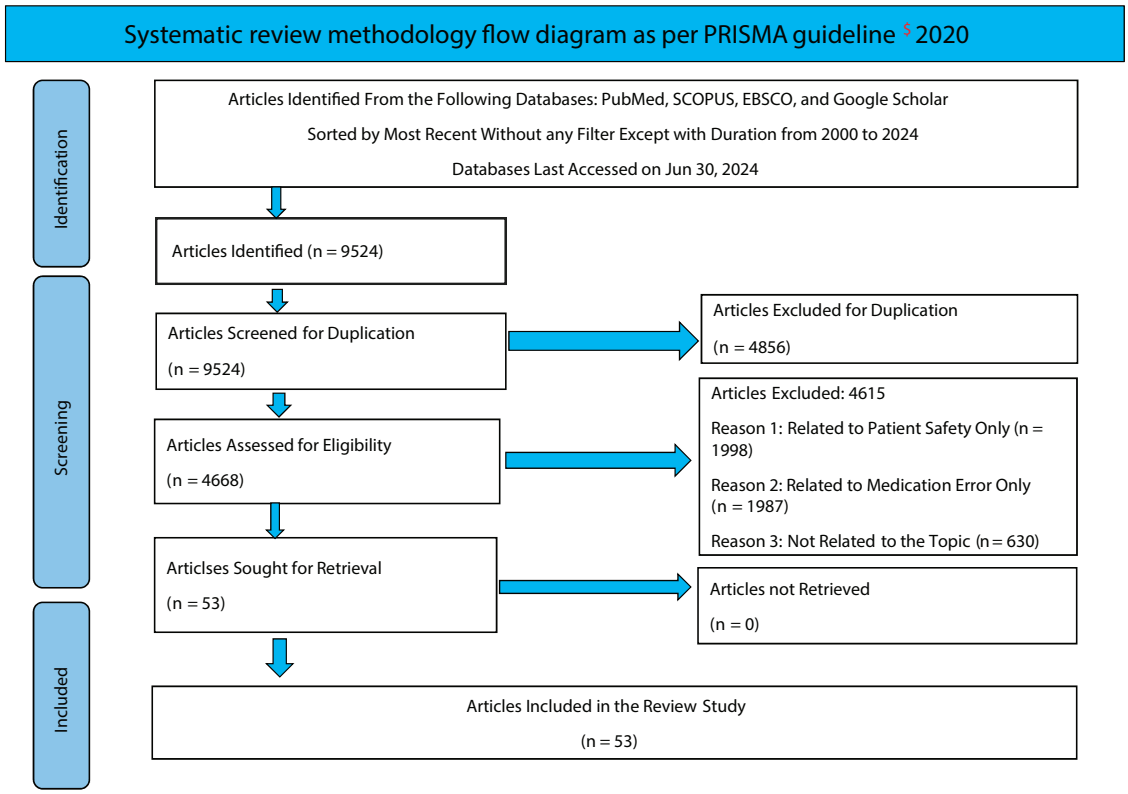

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Figure 1. Systematic review methodology flow diagram (as per PRISMA guideline 2020).

systematic review provides the latest view on CHS technologies applied for patient safety improvement, including medical error reduction.

METHODS

This systematic review was conducted following PRISMA guidelines. The following keywords were used for the search: medication errors, patient safety, and connected healthcare. PubMed, SCOPUS, EBSCO, and Google Scholar databases were chosen, considering their importance, reputation, and indexing for medical field publication. Gray literature was not included in the study. The search results were sorted by most recent only without applying any filters or limits except the duration selected from January 1, 2000 to June 30, 2024 (Fig. 1). Full text articles were retrieved.

The study type and article category of articles were included for the quantitative analysis. All data were expressed as a percentage. Three independent researchers were recruited for screening and to determine the eligibility of the articles. Both were given separate reports and where controversies arose, the two authors acted independently to finalize them.

RESULTS

The literature search found 9524 articles, and 53 of those were found suitable for inclusion in the systematic review.

Of the 53 articles, 10 were review articles (18.9%), and 43 were original (81.1%). No missing or nonretrievable articles were found. Article summaries are given in Supplemental Table S1 (available online).

DISCUSSION

The WHO is implementing the Global Patient Safety Action Plan to prioritize patient safety first in healthcare. The plan seeks to prevent avoidable harm, improve care quality, and accomplish seven key goals. It engages major partners and is consistent with national interests. The strategy aligns with the World Health Assembly's strategic objectives and sustainable development goals (SDGs), promoting good health, gender equality, and reduced inequities.[4,6–11] Medication errors are the most reported in all medical fields. High patient volume, complicated medications, specialized treatment, and aging populations cause medication errors in healthcare. Psychological classification aids in the prevention of these errors,

but poor training, patient characteristics, workload, diversions, and physical concerns all play a role. Improving education and working conditions and developing a national prescription form can assist in preventing errors. Prescription errors, which account for a major share of healthcare errors, are classified as prescribing faults or prescription errors, and monitoring, reporting, and practice modifications are critical.[1,4,5,12–17] The digital health revolution has taken place with the application of numerous technologies in the healthcare system.[18–33] CHS technology is a fast-expanding field that employs technology such as telehealth, telemedicine, and the Internet of Things (IoT) to enhance outcomes, save costs, and satisfy patient needs. It can help prevent pandemics and assure HIPAA (Health Insurance Portability and Accountability Act) compliance. However, you must have the necessary skills and education to use technology. Broadband technology can enhance accessibility and close gaps in the healthcare system. Digital technologies empower mobility-related folks, lowering their dependency on healthcare experts. Telehealth facilities promote patient involvement and self-efficacy.

With Healthcare 4.0, a transformative strategy that considers the social and cultural determinants of health is critical for providing cost-effective, high-quality treatment.[5,18–32,34–50] SMART and connected health (SCH) technology refers to fully connected digital healthcare solutions that can operate remotely. In 2013, the National Science Foundation and the National Institutes of Health together established the "Smart and Connected Health SCH: Connecting Data, People, and Systems" program. SCH employs digital technology, AI, and telecare to improve patient care quality. The COVID-19 pandemic saw the deployment of biosensing wearables as well as smart technologies, such as AI and IoT. Modernization, technological uptake, technical competence, and privacy and security are some challenges.[6–17,29–32,39–45,51–66]

Approaches for Reducing Medical Errors to Improve Patient Safety

Medical errors are avoidable complications of care that cause harm to patients. The 2000 Institute of Medicine (IOM) study intended to reduce mortality by 50%, prompting the development of Medical Error Reporting Systems (MERS). However, healthcare staff underused MERS, contributing to less than 10% of errors. Hospitals use electronic records to detect adverse medication events, and intensive care units use care bundles.[1,4–14,32,39–45,51–53,57–62,67,68] Medical errors are the third leading cause of death in the United States, accounting for 251,000 fatalities per year. To prevent errors, hospitals should invest in technology, foster a "no-blame" safety culture, and solicit feedback. A culture shift toward patient safety, collaboration, and measures such as ideal patient-to-physician ratios are also required. This research investigates the efficacy of mindfulness-based interventions in lowering stress among adult hospitalized nurses, with an emphasis on potential negative outcomes like depression and burnout. It discovers no correlation between intention and actual reporting behavior. [18–32,34–41]

Role of Technology in Reducing Medication Errors and Improving Patient Safety

Several technologies are available that significantly reduce medication errors and improve patient safety. Medication errors are a significant global health hazard, and healthcare technology interventions can help reduce them. Technologies like AI, soft computing (SC), human AI interaction, robotics, health information technology (HIT), EHR, and so on, as well as interdisciplinary collaboration, can improve patient safety and medical diagnostics. Combining AI and SC approaches enhances urban planning and diagnosis. Medical errors, often caused by pharmaceutical use, are a major issue, leading to public confusion and disagreement about patient safety. More research is needed to develop preventative strategies for medication errors. CPOE can standardize orders, improve quality measurement, coding, and billing, and provide decision support. Implementing EHR and CPOE can reduce prescription mistakes, especially in third-world countries. Clinical decision support systems (CDSS) can minimize adverse drug events (ADEs) by up to 70%.[10] Computerized dosage strategies can lower harmful levels in intervention patients and minimize bleeding complications. Combining CPOE with a computerized medication administration record can reduce errors. Automated dispensing, automated drug distribution systems, barcoding, smart intravenous devices, and computerized discharge prescriptions and instructions can improve communication, reduce errors in inpatient settings, and facilitate patient discharge and transfer through electronic medical records. Medication error prevention in outpatient settings requires specific information technology (IT) measures. Computerized prescribing, transcription, robotics, and web-based drug information can reduce errors by over 50%. Personalized websites can improve patient access and administration. Confidentiality concerns must be addressed, and patient inspections of computerized medication records can help. Of US hospitals, 15% have partially implemented CPOE. IT interventions can reduce expenses, with a significant portion coming from averted ADEs. However, further study is needed for each application.[19–32,39–45,52,57–62,76,77]

Impact of Healthcare Technology on Patient Safety

Patient safety in healthcare entails avoiding negative outcomes or injuries. Healthcare technology, which ranges from basic charting to advanced decision assistance, can

Table 1. Barriers and facilitators of connected healthcare technologies

	Barriers	Facilitators
Patient related	Patients frequently struggle to use personal health records for medication reconciliation due to variables such as lack of IT skills, literacy, poor memory, computer access, trust, and motivation.	Patients value the PHR for its clarity, emergency support, and patient involvement in treatment, as well as the fact that it may be used without the supervision of a healthcare provider.
Application related	Many older patients find it difficult to use a PHR, although few admit it. Common impediments include difficulties registering, changing account information, and asking for passwords, as well as malfunctioning PHRs.	Patients advise making PHRs more usable by simplifying and structuring information, adding digital communication with healthcare practitioners, and implementing drug monitoring to reduce drug interactions and duplication.
Process related	Patients questioned the duty of updating drug information into a PHR, with some claiming that an HCP should be held accountable for correcting obsolete medicines, while others questioned the patient's accountability.	Patients recommend that hospitals use PHRs for IT-skilled, drug-aware, and younger patients, do additional checks, and update prescription lists regularly to increase patient satisfaction.
Context related	Patients are dissatisfied with HCPs' usage of applications without data transmission, deeming PHRs useless and their information underused, emphasizing the need for better data management and transfer.	Patients feel that healthcare HCPs are critical to increasing the use of PHR. They recommend offering more information, assisting patients, and exchanging data across applications.

HCP: healthcare provider; IT: information technology; PHR: patient health record.

enhance patient outcomes by minimizing errors, simplifying care coordination, and monitoring data.

The text provides a systematic review of various studies on using electronic tools for physician shift-to-shift handoffs, barcode technology, smart pumps, telemedicine, telepsychiatry, incident-reporting systems, and electronic medical records in the American health system. It also discusses the benefits and risks of these technologies, policy recommendations for telemedicine in primary care settings, and the effectiveness of incident-reporting systems in improving patient safety. Automated medication dispensing technology in hospitals automates drug management and reduces workload, but the evidence is limited to critical care situations. Retained surgical items prevention technology uses radiofrequency identification (RFID) tagging instead of manual counts. Patient electronic portals provide secure online health information; however, there is little evidence of increasing patient safety. Telemedicine uses telecommunication technologies to communicate between patients and providers, but there is limited evidence of patient safety. Electronic incident reporting systems allow healthcare practitioners to record safety events, but there is little evidence of preventing medical errors.[4–11,18–32,35,37–41,51–53,78–83]

Barriers and Facilitators

The study investigates patients' opinions of barriers and facilitators in using a patient health record (PHR) for medication management before hospital visits. It lists 14 barriers and 10 facilitators in four related areas (Table 1). The study recommends removing barriers, improving information providing, and addressing practical concerns to improve PHR usage and adoption.[1,15–27,30,32,34–45,57–62]

Patients cited a lack of clarity on the purpose and existence of a PHR, including feedback and data access. They also noted that issuing the invitation too early could result in medication adjustments or forgetfulness. Finally, patients voiced privacy concerns about adopting an EHR, citing sensitive information and potential hacking dangers, as well as the possibility of personal information becoming widely available online[25–33,39–42,44–46,57–62]

Challenges and Lessons Learned

Medication mistakes in ambulatory practice account for one of every 131 outpatient deaths in the United States.[31] Automated drug lists and computerized prescribing systems can help improve patient safety, but compatibility and uniformity are essential. COVID-19 has accelerated digital transformation in healthcare, necessitating shared accountability and engagement with EHR vendors.[7–17,23–32,34–45,54,55,57–61,86] Sittig et al.[11] identified challenges through an iterative process so that healthcare organizations, HIT developers, researchers, policymakers, and funders can focus their efforts where they are needed most and categorize these challenges into the stage of the health IT lifecycle where they appear, including (1) design and development, (2) implementation and use, and (3) monitoring, evaluation, and optimization (Table 2).[16–32,34–38]

Healthcare technology safety needs improvement because of nine challenges. Rapid global adoption and increasing errors are causing issues. Organizational solutions for design, testing, and incident monitoring are crucial. Incorporating evidence-based nursing and health informatics literature into strategies can enhance safety.[1,7–24,35–38,41–45,54,55,57–62]

Table 2. Challenges of connected healthcare technology

A. Design and Development Challenges	B. Implementation and Use Challenges	C. Monitoring, Evaluation, Optimization Challenges
• Proactive models for detecting clinical application flaws and managing risks. • Poor user interface design in EHRs, ICUs, vital sign monitors, and infusion devices. • Prioritizing IT component safety through the FDA's precertification procedure. • Patient safety hazards: maintaining accurate patient matching across systems.	• Improves safety by recognizing errors and making informed decisions. • Requires AI-powered automation while preserving human awareness. • Interruptive warnings should bear clinically evident information. • Proper approaches are crucial for safety concerns during system transitions.	• Real-time automated surveillance for system performance and safety. • Proposal for a blame-free reporting system for EHR-related patient safety risks. • Increased responsibility of consumers and caregivers for health information management.

AI: artificial intelligence; EHR: electronic health record; FDA: Food and Drug Administration; ICU: intensive care unit; IT: information technology.

Future Research Needs

Healthcare providers, patients, and regulators are all using connected health technologies to enhance patient safety, reduce harm, and improve outcomes. However, the unknown influence on patient outcomes, particularly the high cost of deploying computerized infrastructures, continues to be a substantial impediment. A systematic study indicated that health IT improved patient safety outcomes in 69 research articles, with the highest positive results shown in inpatient trials and clinical decision support. More thorough research is needed in long-term care and ambulatory settings. Future studies should concentrate on patient safety results, instrument characterization, and cross-institutional comparisons. Further research is required to determine which types and attributes of the technology enhance patient care.[1,5–14,18–33,38,45,46,54,55,57–62,85,86]

This study may have been limited by only searching four databases and excluding gray literature.

CONCLUSION

Patient safety has improved, and medication or medical errors have been reduced through a variety of techniques and advancements, but the Golden Era is being realized through excellent healthcare methods. This includes tackling issues, including outpatient care harm, diagnostic errors, and HIT. Technology can provide benefits, but it is critical to weigh safety evidence and take a balanced approach. Connected healthcare technology is transforming the industry by boosting safety and efficiency, as well as meeting the complex needs of aging populations and long-term conditions. AI has the potential to revolutionize healthcare, but frequent monitoring is required to maximize outcomes and assure its effectiveness in decision-making. Healthcare technology evaluation is challenging because of transformational and organizational changes. Mixed-methods approaches and realism studies are needed to evaluate the quality and safety of developing technology. Implementers and evaluators must work together to balance innovation with practical safety concerns and reduce pharmaceutical errors.

Supplemental Material

Supplemental materials are available online with the article.

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