theJournals

Sports, Health & Wellness Insights, e-ISSN: 3107-7617
July-December 2025 | Volume: 01, Issue: 02, Page No.: 51-64
https://doi.org/10.64006/shwi/1205

**REVIEW ARTICLE** | **Received**: 14th Ocotober. 2025| **Revised**: 10th November. 2025| **Accepted**: 13th December 2025| **Published**: 24th December. 2025

# Digital Transformation in Medication Safety: A Systematic and Bibliometric Analysis of High-Alert Medication Management in Healthcare Settings

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## ABSTRACT

The use of high-alert medications such as anticoagulants, insulin, and chemotherapeutic agents is associated with a significant risk of harm to patients because of their narrow margin of safety and complex methods of administration. Medication errors remain a major problem in healthcare institutions that continue to rely on manual, paper-based systems for prescribing, dispensing, and administering medications. Digital transformation has therefore emerged as a central area of focus for improving medication safety and reducing the incidence of preventable medication errors, particularly for the subset of drugs that carry the greatest potential for catastrophic harm.

By means of both systematic literature review and bibliometric analysis, this systematic review allows for mapping of the academic landscape in terms of the influence of digital transformation on high-risk medications safety and development of future research areas focusing on the interaction between digital healthcare technologies and the management of medications and patient safety associated with the usage of high-risk medications.

The systematic literature review and bibliometric analysis of publications from 2019 – 2025 were carried out in accordance with PRISMA guidelines to enable testing and replication of the methodology. The relevant literature was obtained from the key databases, such as Scopus, PubMed, and Google Scholar, and was analyzed using inclusion and exclusion criteria. The analyzed studies were analyzed with the help of R-compatible Bibliometrix and its Biblioshiny module, which enables analysis of the features of the publication and significant works on the topic.

As a result, there were 60 papers included into this research. The study found that electronic technology, including e-prescribing, clinical decision support system (CDSS), barcode medication administration (BCMA), and e-medication administration records (eMAR) brings the decrease in medication administration errors and increases the level of safety for patients. Thematic analysis produced three dominant research themes: patient safety, high-alert medications, and intensive care. Bibliometric analysis showed that the volume of published research has increased steadily since 2021 and that international research collaboration, while present, remains moderate at 13.33 percent.

Digital technology has been identified as an important enabler of a safer system for managing high-alert medications by increasing accuracy, standardization, and clinical decision-making through the provision of real-time information. Nonetheless, challenges related to system usability, technology infrastructure, and workforce readiness must be addressed for digital transformation to be effective. Achieving sustainable improvements in medication safety and overall healthcare quality will require strategic action plans that integrate technology adoption, staff training and education, and the development of supportive institutional policies.

**Keywords:** *High-Alert Medications, Patient Safety, Digital Health, Medication Errors, Bibliometric Analysis*



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**How to cite**: Zia, H., Khan, S., Chaudhary, B., & Rasool, I. (2025). Digital transformation in medication safety: A systematic and bibliometric analysis of high-alert medication management in healthcare settings. *Sports, Health & Wellness Insights*, *1*(2), 51–64. https://doi.org/10.64006/shwi/1205

## INTRODUCTION

All healthcare systems across the globe recognize medication safety as a fundamental pillar of quality health care delivery. Because of the potential for serious patient harm when used incorrectly, high-alert medications such as anticoagulants (for example, heparin), insulin, concentrated electrolytes, and chemotherapeutic agents require heightened scrutiny at every stage of the medication-use process. These medications typically possess a narrow therapeutic index, meaning that even a small variation in dose can lead to a serious adverse drug event, so healthcare professionals must prescribe, dispense, and administer them with precision to mitigate the risk of adverse drug events, prolonged hospital stays, and escalating healthcare costs (Aseeri et al., 2020). In response, patient safety organizations have designated high-alert medications as priority medications warranting additional monitoring and dedicated safety protocols.

The problem of medication errors carries on being critical and prevalent in contemporary medicine, ranking among the most significant sources of preventable injuries to patients. Errors can take place within different stages of the medication-use process, with processes like prescription, transcription, distribution, and administration being involved. Some of the contributing factors include complicated medication protocols, burdening work, poor interpersonal communication among workers, inefficient documentation systems, inadequate training in the principles of safe medication administration (Kuitunen et al., 2023).

Intensive care units and emergency departments are even more critically affected because of the possibility of working with many patients in need of urgent medical assistance at the same time.

Many investigations show that dangerous medications represent over-represented groups in accounts of serious medical errors and serious adverse effects due to their complicated administration protocols and toxicity (Aseeri et al., 2020). Further analysis of adverse drug events reporting systems allows to make a conclusion that the number of high-alert drugs is rather limited while the harm they bring is considerable.

The heightened risks are bringing attention to the accreditation agencies present in health care systems. In India, the NABH recognizes the safety of the medications as one of the key dimensions of healthcare security. This is at the same time, the International Patient Safety Goal gives emphasis on the safe management of the high-risk medications which means there is a need for proper policies regarding the correct identification, storage, prescription, dispensing, and monitoring of the high-risk agents. By following these standards an organization can use uniform processes and labels in medication management and thereby reduce the chances of medication errors.

However, while following the guidelines, a number of healthcare institutions continue working with manual and paper-based medication management systems thus enabling the occurrence of multiple mistakes like illegible handwriting, incompleteness in prescriptions, transcription failure, and delays in communication. Also, the lack of proper knowledge and training of the personnel leads to the increased number of medication mistakes.

The problems have been tackled by current trends in digital transformation. Digital healthcare methods are represented in electronic prescription systems (EPS), clinical decision support systems (CDSS), barcode medication administration (BCMA), and electronic medication administration records (eMAR), thus transforming medication management through the introduction of standardized protocols, accurate documentation, and real-time notifications about contraindications, drug interaction, and overdosing. Thanks to eliminating the heavy reliance on manual techniques, the technologies promote the minimization of typical errors made by specialists.

Electronic prescription systems deal with illegibility and ambiguity of prescriptions by confirming the drug presence and examining its formulation compatibility and dosage. Moreover, with barcode medication administration allowing for patient identification and medical product identification, as well as verification of dosage and administration time, it is possible to lower the amount of mistakes made by physicians. Through electronic medication administration records, it becomes much easier for companies to track medication usage and comply with safety regulations.

The efficacy of digital interventions has been confirmed in many studies. It has been shown that using structured labeling in medications and strict processes of verification decreases the number of mistakes in administering medications in the field of intensive care medicine (de Kassio Nunes et al., 2025). Organizational vertical double-checking standards based on digital systems have reduced medication administration errors in various areas, especially

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in pediatric intensive care (Konwinski et al., 2024). Clearly, combining modern technologies with formed safety standards brings significant outcomes.

Although having advantages, it is difficult to implement. Experts point out complexity of the systems, increased burden of documenting everything and alert fatigue because of excessive notifications and solve the problems of budget and technology. These challenges require organizations to create strategies, get support from leaders, and implement training programs. Actual studies seek new methods to reduce medication risks. Studies of root causes demonstrate that human factors, problems with workflows, and problems with design need to be addressed, and different mapping techniques and standard safety schemes are being developed to identify the problems.

Despite the fact that many studies have addressed the relationship between the safety of drugs and modern health technology, this industry is still in disarray because many research projects study different procedures or contexts separately. As a result, systematic literature reviews and quantitative analyses of the subject matter are necessary to understand how the area has developed and find out important frameworks in it. The objective of this particular research is to bridge this void by analyzing the way in which digitalization affects management of medications categorized as high-alert. The methodical literature review conducted within the framework of the research is based both on the PRISMA guidelines used in gathering, screening, and selecting the literature from 2019 to 2025 and a bibliometric study carried out through the Bibliometrix package in the R statistical programming language, which allows researchers to find out who is a lead researcher in the field, who collaborates with whom, and what the trends are. Thus, it is expected that the research will help identify important technological advances, gaps in research, and evidence-based solutions that can be of use for experts in the field.

**Research Question**

The research question which directed this study was: In what way has the adoption of digital technologies in healthcare impacted the development of research and practices regarding the management of high-risk medications and medication safety in healthcare institutions, as shown by the systematic and bibliometric analysis of the existing literature?

**Research Objective**

The aim of this study is to provide a comprehensive mapping and analysis of the academic field of digital transformation in high-risk medication safety through the use of systematic literature review and bibliometric methods. The study will attempt to identify significant trends in research and new thematic areas that connect the use of digital technologies in healthcare positively affecting the management of medications and the safety of patients.

## METHODOLOGY

The purpose of this research is to analyze and evaluate the domain of digital transformation in terms of two main areas: high-alert medications management and digital solutions aimed towards improving patient safety. To conduct this literature review, a thorough bibliometric analysis was carried out in combination with the systematic literature review methodologies which allows defining the most important notions in this field of research. The bibliometric analysis provides researchers with the framework for considering the key findings of the literature, determining behavior which is characteristic for publications in this area, revealing the dynamics of the publications beginning from the origin of the field, and searching for the important trends related to the usage of digital interventions in the sphere of medication safety.

In order to achieve this aim, the used approach for the systematic review included the analysis of literature published from the year 2019 till 2025 while also ensuring that every study meets the quality requirements for replicability as prescribed by the PRISMA guidelines. The studies that were taken into consideration came from three main databases, namely Scopus, PubMed, and Google Scholar, were subjected to additional screening as to meet the predetermined inclusion/exclusion criteria. After the studies had been singled out, a bibliometric analysis using the Bibliometrix library for R and the online tool Biblioshiny was performed in order to look into such aspects as publications, important studies, collaborations, etc.

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### Data Acquisition and Search Methodology

In order to collect relevant articles published from 2019 to 2025 concerning the impact of digital transformation on high-risk medication safety, a thorough literature review was performed using search string shown in Table 1. The literature review was restricted to the English language only and included searches through databases including Scopus, PubMed, and Google Scholar. The search was based on the following keywords: high-alert medication, medication safety, and digital health technologies. Each section of the keywords was further divided into synonymous words, making use of the Boolean operator "OR." All three keyword sections were combined using the Boolean operator "AND." The search was ultimately designed to be comprehensive enough to provide a wide literature sample, while generating specific and useful results for every retrieved record.

**Table 1.** ***Search Strategy***

| Component | Description |
|---|---|
| **Research question** | How do digital health technologies contribute to strengthening high-alert medication safety in healthcare settings? |
| **Key concepts or terms** | High-alert medications, medication safety, digital health technologies |
| **Databases or sources** | Scopus, PubMed, Google Scholar |
| **Time period** | 2019 to 2025 |
| **#1** | "high alert medication*" OR "high-risk medication*" OR insulin OR anticoagulant* OR heparin OR chemotherapy |
| **#2** | "medication safety" OR "medication error*" OR "patient safety" OR "drug safety" |
| **#3** | "digital health" OR "electronic prescribing" OR "clinical decision support system*" OR "barcode medication administration" OR "electronic medication record*" OR "health information technology*" |
| **Final strategy** | #1 AND #2 AND #3 |

*Source: Author's Compilation*

### Inclusion and Exclusion Criteria

The inclusion criteria comprised articles published in English, peer-reviewed, addressing high-alert or high-risk medications, medication safety, or digital health technology, published between 2019 and 2025, and originating from a hospital, clinic, or critical care setting that provided empirical or review-based evidence.

The exclusion criteria comprised studies published before 2019, studies not published in English, and studies unrelated to either high-alert medications or digital health technology. Editorial commentary or conference abstracts without accompanying full text were also excluded, as were studies lacking sufficient methodological detail. Duplicate records and studies not conducted within a healthcare setting were removed to ensure the relevance and quality of the final candidate pool.

### Screening and Data Retrieval

This study was conducted with the use of the PRISMA guidelines during the selection process. The first step in the selection of relevant literature was the removal of duplicates. Following this, the titles and abstracts of each of the chose studies were scanned to eliminate studies that had no connections to the goals of the present study. The not relevant studies were eliminated right away.

The next step was to review the full text of eligible articles according to the predetermined criteria for inclusion and exclusion. To avoid bias, two reviewers screened all relevant studies independently and any disagreements were solved by informing a third reviewer. After that, a structured data extraction form was used to extract data from the electronic files of the final list of studies contained in the database.
The data extraction form served its purpose and included most important variables related to thematic and bibliometric analyses of literature such as the name of authors, year of publication, country, methods of the study, type of healthcare setting, type of high-risk medication that was studied, and important results. The structured dataset was meant to give a deep understanding of general trends in the research area of digital transformation.

**Data Analysis**

In this research, the combination of systematic literature review and bibliometric methods provides good results in understanding the territory better, since both qualitative and quantitative analyses have been performed. The systematic literature review was based on the PRISMA framework that allowed for developing a systematic approach to identifying, screening, and selecting studies. The bibliometric study was performed using R software taking into account both Bibliometrix and Biblioshiny packages and was applied for the quantitative analysis of the research domain.
This involved using bibliometric techniques to determine descriptive indicators such as trends in publishing over the years and characteristics of the analyzed articles and most cited papers. In addition to bibliometric methods, visual methods of analysis were also implemented including thematic ones to uplift the areas of research and the intellectual basis of literature. Combining the systematic and bibliometric analyses allows performing both thorough qualitative interpretation and precise quantitative estimation of the literature on high-risk medication safety in the context of digitalization process.

## RESULTS

### Systematic Literature Review

The database search yielded a total of 2,297 records spread across selected databases (see figure no 1). After removing 1,065 records that were duplicates, the other records were screened, resulting in the exclusion of 1,114 studies that were deemed irrelevant based on their title and abstract review. After full-text assessments were conducted on the remaining studies, 60 studies were deemed eligible and thus used in the review (see figure 1 for more details).
The studies conducted were mainly based in Asia and Europe to indicate that medication safety through technology is gaining traction in these areas. Most of the studies were done in hospital and critical care settings with focus being put mostly on the high-risk forms of medication such as anticoagulants, insulin, and oncology drugs. Many of the articles in the review discussed topics like electronic prescribing systems, barcode medication administration, electronic medication administration records, and clinical decision-making support. Most articles in the review employed either quantitative measures or mixed methods to discuss their findings. Furthermore, most of the literature analyzed after 2020 signifies an enhancing focus on the need to conduct research in the area of digital health technologies.

### Descriptive Analysis of Reviewed Articles

Bibliometric analysis relies on a standard, transparent technique for analyzing voluminous scientific works on significant subjects that explore publication patterns, research tendencies, and common areas of interest, among other things. In the current paper, a bibliometric study of high-alert medications and digital transformation is presented, based on 60 publications made during the period of 2019 to 2025 in 42 periodicals gathered in Table 2.

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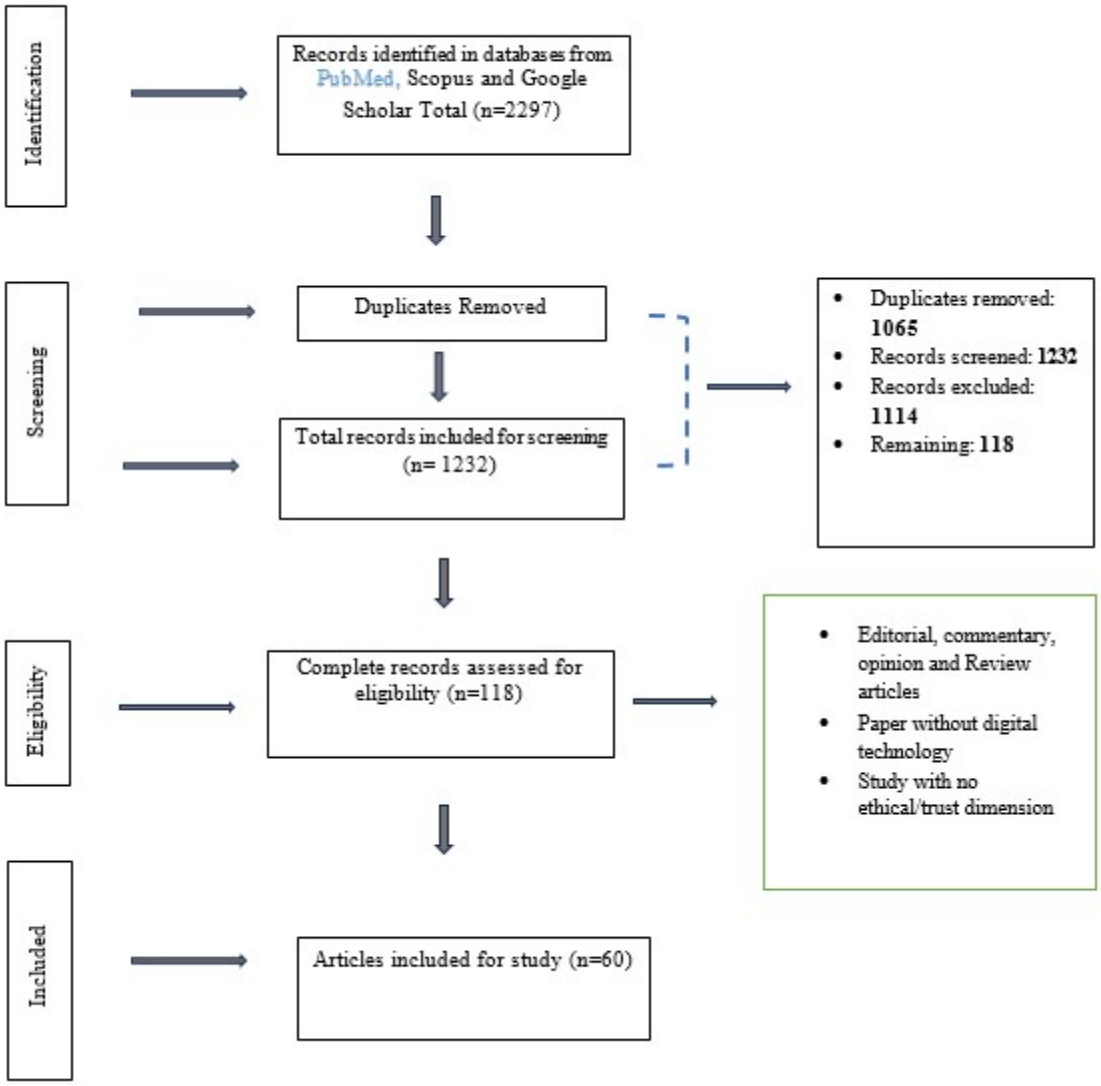


**Figure 1:** ***PRISMA flowchart***

*Source: Author's Compilation*

**Table 2.** ***Descriptive Analysis of Reviewed Articles***

| Description | Results |
|---|---|
| **Timespan** | 2019:2025 |
| **Sources (Journals, Books, etc.)** | 42 |
| **Documents** | 60 |
| **Average citations per document** | 5.017 |
| **Keywords Plus (ID)** | 681 |
| **Author's Keywords (DE)** | 177 |
| **Authors** | 274 |
| **Authors of single-authored documents** | 4 |
| **Co-Authors per Document** | 4.9 |
| **International co-authorships (%)** | 13.33 |

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*Source: Constructed by Authors Using Biblioshiny*

The obtained data included 681 references Keywords Plus keywords and 177 author's keywords, which can be considered a broad multidimensional scope of research activities in the area. The average citation rate of articles totaled 5.017, which indicates the average level of science inquiry. Among 274 authors involved in the research, only four worked individually and the rest of the authors published as a part of collaborative efforts with an average number of coauthors equaling 4.9, pointing to the interdisciplinary nature of research on digital health and medication safety. The percentage of international collaboration was 13.33 that shows that although this area is still developing, many countries become involved in global research projects nowadays.

**Annual Scientific Production Analysis**

The annual rate of scientific production displays the trajectory of research in digital transformation and safety of high-alert medications over the period. In line with the evidence presented above, variations in the amount of research output each year show a different level of involvement of researchers each year.

The trend begins with a large volume of publications in 2019 and drops sharply in 2020 probably due to several disruptions to research activities. Starting from 2021, there is a persistent rise in research publications. The upswing shows sustained interest and suggests that researchers resumed their momentum regarding digital health technologies and safety of medications.

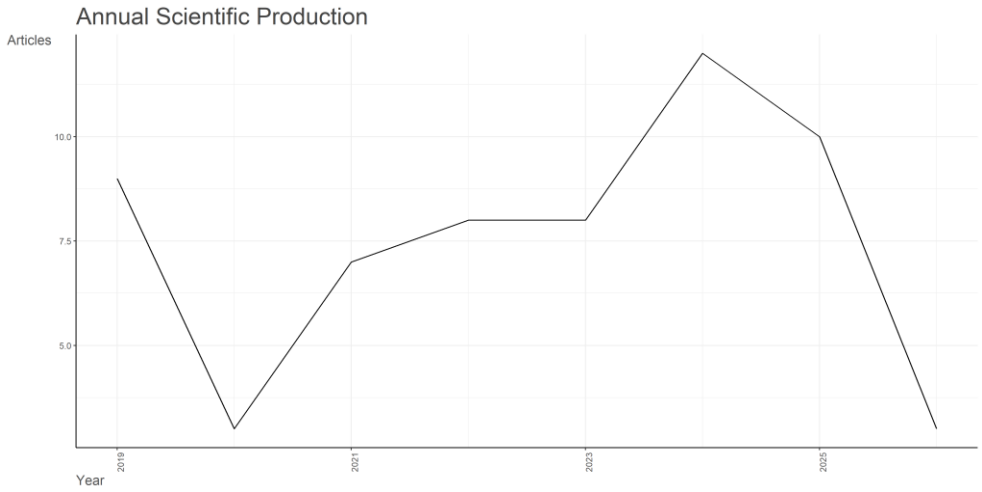


**Figure 2:** ***Annual Scientific Production***

*Source: Constructed by Authors Using Biblioshiny*

The maximum displayed in 2024 is the highest amount of research published in the examined period due to increased focus on digital health systems and more wide application of electronic medication administration techniques as well as general global interest in safety of patients as shown in the Figure 2,. The small decrease in 2025 followed by the larger drop in 2025 can be explained not only by the time of the research being incomplete but also by the fact that the year of 2025 has not finished yet.

**Citation Analysis**

The number of citations is a significant way of estimating the degree of influence of the research. The authors summarized the total citations, the total number of citations adjusted for the publication year, and citations per year, in the below Table 3.

The total citation analysis shows that Sessions LC (2019), published in the Journal of Advanced Nursing, is the most highly cited paper in the review, and that paper has 23 citations in total. Linden-Lahti (2021), both published in the Journal of Patient Safety, showed the next value, 16 citations in total, which demonstrates that patient safety research is very significant in this field. The normalized citation analysis allows for a more precise comparison between academic publications as it takes into account the influence of the years of publication the highest normalized citation score (5.79) and the highest annual citation value (4.67) are displayed by Wischmeyer (2024), one of the articles published in the American Journal of Health-System Pharmacy.

**Table 3: Top 10 Most Cited Articles**

| Paper | DOI | Total Citations | Normalized TC | TC per Year |
|---|---|---|---|---|
| **Yu D, 2021, Applied Clinical Informatics** | 10.1055/s-0041-1730031 | 15 | 1.15 | 2.50 |
| **Wischmeyer PE, 2024, American Journal of Health-System Pharmacy** | 10.1093/ajhp/zxae079 | 14 | 5.79 | 4.67 |
| **Tyynismaa L, 2021, Journal of Patient Safety** | 10.1097/PTS.0000000000000388 | 16 | 1.23 | 2.67 |
| **Sessions LC, 2019, Journal of Advanced Nursing** | 10.1111/jan.14173 | 23 | 2.88 | 2.88 |
| **Schepel L, 2021, Journal of Patient Safety** | 10.1097/PTS.0000000000000512 | 12 | 0.92 | 2.00 |
| **Ruutiainen HK, 2021, European Journal of Hospital Pharmacy** | 10.1136/ejhpharm-2020-002531 | 13 | 1.00 | 2.17 |
| **Marwitz KK, 2019, Research in Social and Administrative Pharmacy** | 10.1016/j.sapharm.2019.02.007 | 13 | 1.63 | 1.63 |
| **Lineberry E, 2021, American Journal of Emergency Medicine** | 10.1016/j.ajem.2021.04.054 | 13 | 1.00 | 2.17 |
| **Linden-Lahti C, 2021, Journal of Patient Safety** | 10.1097/PTS.0000000000000914 | 16 | 1.23 | 2.67 |

| | | | | |
|---|---|---|---|---|
| **Kim MS, 2019, BMC Health Services Research** | 10.1186/s12913-019-4194-y | 12 | 1.50 | 1.50 |

*Source: Constructed by Authors Using Biblioshiny*

Various research works from 2021, like those of Yu et al. (2021), Schepel et al. (2021), Ruutiainen et al. (2021)and Lineberry et al. (2021)continue to gain citations even after their release. Thus, it may be said that 2021 has been a highly productive year in terms of crucial research works in this field. This is different from the relatively older research works completed by Marwitz et al. (2019)and Kim and Kim (2019). They also enhance knowledge in the field, but the number of citations is much less compared to the more recent works. Overall, it may be concluded that older researched articles reached higher total number of citations, while newer scientific papers have higher yearly citation rates.

### Thematic Map Analysis

The algorithmically generated thematic map derived from bibliometric analysis shows how the concept of digital transformation in relation to medication safety has evolved in two dimensions, i.e. centrality or relevance (indicated by the x-axis), which reflects the interaction of the theme with other themes, and density or development (shown on the y-axis), which indicates the strength and the maturity of the theme. Using these two criteria, the themes can be classified in four quadrants as given in the below Figure 3: motor themes (high centrality, high density), niche themes (low centrality, high density), emerging or declining themes (low centrality and density), and basic themes (high centrality and low density).

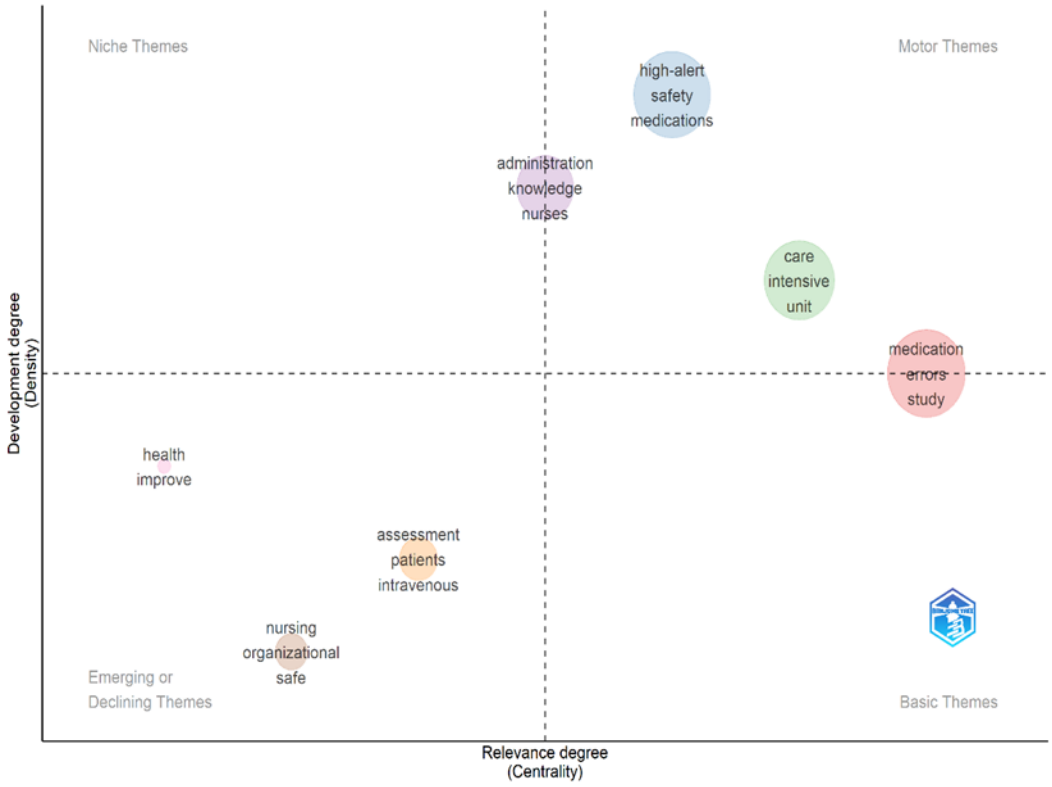


**Figure 3:** ***Thematic Map of Reviewed Literature***

*Source: Constructed by Authors Using Biblioshiny*

**Cluster 1: Core Safety and High-Alert Medication Management (Motor Themes)**

This cluster indicates that the area of research development has reached the highest maturity level and is located in the central part of the discipline. The cluster consists of high-alert medications, safety, intensive care unit, care, etc. Because of high centrality and density of the present theme, it may be concluded that the conceptual development of the subject under consideration is well-established and there are a lot of connections within the theme. The cluster indicates that research is aimed further at the field of patient safety and high-alert medication under conditions of intensive care unit.

**Cluster 2: Medication Error and Patient Safety Concerns (Basic Themes)**

The second cluster, which focuses on medication errors, belongs to the basic themes category which is associated with many other topics that have lower thematic specialization in comparison with the first cluster. Medication error prevention continues to be topical; however, studies on different digital technologies for prevention, such as artificial intelligence, predictive analytics, and automated safety systems, have yet to be conducted. The literature emphasizes the fact that more attention is given to technology adoption for prevention purposes than to identification of the errors.

**Cluster 3: Human Factors and Clinical Practice (Niche Themes)**

Niche themes such as "administration," "knowledge," and "nurses" fall within this cluster. Although relatively well developed internally, their lower centrality indicates that they remain less connected to the broader discourse on digital transformation. This suggests that while research on nursing practice and healthcare professional knowledge is abundant, it has not been fully integrated with newer digital technologies — a gap pointing to an urgent need for improved interaction between human factors, clinical workflows, and digital systems.

**Cluster 4: Organizational and Emerging Research Areas (Emerging/Declining Themes)**

Themes in the fourth cluster include "safe," "nursing," "organizational," "assessment," "patients," and "intravenous" and are mainly in either of the two quadrants capturing the developmental stages of themes. This implies that although patient-centered, organization-oriented, and safety-oriented assessment methods are still at the nascent stage, they can provide new ideas for further advancement in connecting policies and workflows with the help of technology.
The findings thus point to the idea that the field appears to be grounded on popular safety practices and major healthcare settings but lacks in developing the human, organizational and technological aspects of the topic. Motor themes indicate that the area is well developed, while the absence of basic and niche themes highlights that there is still much potential in the area waiting to be tapped.

## DISCUSSION

This study illustrates the influence of digital technology in improving the use of safer practices in the administering of medications, resulting to reduction of errors and overall safety in healthcare. Digital solutions received more acknowledgment as helpful in decreasing medication errors. The earlier studies established insulin, anticoagulant and chemotherapy drugs as the most dangerous drugs resulting to undesired side effects due to their narrow therapeutic index and complicated dispensing (Aseeri et al., 2020). Research substantiates that the documentation based on paper systems is ineffective in managing associated danger in situations of high stress.

The key finding shows that digital technology has essential importance for accurate prescribing and safe medication dispensing. The majority of reckoned studies prove that e-prescribing systems help to diminish errors caused by poor handwritings and incomplete prescriptions, that health care provided by clinical decision support system sends alerts

in real time for avoiding adverse drug interactions and wrong doses (Konwinski et al., 2024), and barcode medication administration promotes nurses complying with the 5 rights principles of correct administration and avoid mistakes. These results corroborate previous studies highlighting the usefulness of digital technology in decreasing mistakes and enhancing patient safety in their care.

The different thematic analysis results depict that the area tends to focus on the crucial question of safety and critical healthcare situation including intensive care, which aligns with earlier research that in such complex situations it is vital to ensure effective systems for medication safety (de Kassio Nunes et al., 2025). This tendency of the theme can be evidenced by the importance of the topic relating to the well-known terms of "high-alert medications" and "safety".

Medication errors appear to be one of the key themes, which indicates that even though it is widely researched area, further studies are still needed to investigate the essence and application of medication safety in the world where digital transformation occurs. The trend of moving from error detection to providing technical solutions can be observed, as for instance technologies such as AI and predictive analytics will play an increasingly important role although their usage in clinical practice remains unsatisfactory.

Another major takeaway is about human factors and organizational processes. Nursing knowledge, administration methods, and organizational safety process appears as niche or developing themes which means that they are not yet established in the realm of digital health research. Previous studies show that it is not enough to have a technical know-how for the effective launch of the system. Some factors must be taken into account to ensure a success includinguser acceptance, training, and integration of the new procedures into the routine process.

Bibliometric results also show positive changes in the world-wide research output since 2021. The international cooperation rate is 13,33% which indicates that in future there must be a progress in cross-country associations and cooperation in order to carry out knowledge dissemination and implement innovations into practice.

While digital technologies have great potential, there are still some obstacles such as complexity of the system, overload of alerts, reluctance to change, and limited resources. These barriers can be overcome only by means of careful planning, reputable investment into the infrastructure, and constant education of the staff.

The results of this study back the importance of applying the standards set by the National Accreditation Board for Hospitals which is evident in the example of the international framework, IPSG 3. This is the framework to provide safe management of high-risk drugs. Different technologies provide ample opportunities of implementing the mentioned standards through tracking how drugs are used in practice and make sure that protocols set for their use are being followed. The authors managed to synthesize the existing knowledge in the area of the study in order to map the whole intellectual structure of this research direction. Thus, it comes as evidence of how digital technologies can help improve medication safety and find some difficulties in the described area that have to do with human factors, organizational integration and new technologies. In the future, further studies should focus on the literature onartificial intelligence, machine learning, and predictive analytics in the above-mentioned systems as well as country-specific studies and interdisciplinary investigations on how technology can be introduced in clinical practice.

## CONCLUSION

This study analyzed the relationship between digital transformation and increased safety for high-alert medications in healthcare settings through a combination of systematic literature review and bibliometric analysis. Digital health technologies, including electronic prescribing systems, clinical decision support systems, barcode medication administration, and electronic medication administration records, were found to be significant contributors to reducing medication errors, improving workflow efficiency, and enhancing patient safety outcomes (Konwinski et al., 2024). These technologies were shown to address major deficiencies associated with traditional, paper-based medication management systems while also strengthening safe clinical decision-making.

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In addition to examining the specific digital health technologies noted above, this study found a significant increase in scholarly output in this area over the past decade, with digital health technologies constituting the primary focus of much of this work. A continued gap remains, however, in the integration of human factors, organizational practices, and emerging technologies within digital medication safety frameworks. The ongoing presence of significant medication-related risks and adverse events associated with high-alert medications indicates that enhanced safety systems supported by digital innovation remain essential (Aseeri et al., 2020 ).

This research study indicated that although digital transformation has a lot of advantages with respect to the use of high-risk medicines, it is very important to have a good balance in the drug delivery approach with digital transformation and training, organizational support, and policies that are compatible with the technology being used. Therefore, further studies should shift the scope of research to more sophisticated technologies such as artificial intelligence and predictive analytics. Besides, great attention should be paid to cooperation between disciplines and implementation strategies that take into account the context of usage.

## LIMITATIONS

Although this paper provides useful information on the role of digital transformational technologies in the area of the safety of high-security medicines, this research has a number of limitations that can affect the results. For instance, the analysis conducted for this paper only covered studies published in English from the year of 2019 to the year of 2025, ignoring the research done in other languages. Moreover, the authors may miss some articles that were not included in Scopus, Google Scholar, and PubMed and were published in other libraries. Secondly, the outcomes are reliant on how well designed, and the overall quality of the studies that are selected; since variability of methodology, sample size, and approach of analysis may influence the reliability of results, whereas bibliometric studies provide key data on publications and citations, they might not always reflect the effectiveness of these interventions clinically and practically.

Additionally, thematic analysis consists of classifying literature, meaning that this process has a degree of subjectivity. The absence of empirical primary data does not allow for assessing adoption issues and functioning in different types of health care settings, and the gaps in research of context factors also prejudices the findings. All these limitations lead us to the conclusion that there must be caution while interpreting this bibliographic review and that empirical context-specific research should contribute to bibliometric studies in the future.

## FUTURE SCOPE AND RECOMMENDATIONS

The outcomes generated by the study propose the necessity for a proactive and holistic stance of the healthcare systems regarding digital transformation initiatives directed towards medication safety enhancement. Future research should include more resources, involving grey literature and multilingual investigations, which will strengthen the experimental part and confirm results by longitudinal designs regarding the efficiency and cost-effectiveness of digital interventions. Sophisticated analytic techniques should enhance the reliability and objectivity of the bibliometric and thematic study.

The successful introduction of sophisticated digital systems electronic prescriptions, clinical decision support, barcode medication administration, electronic medication records have to involve a lot of efforts from all the participants of healthcare processes (Konwinski et al, 2024), the healthcare organizations have to invest in the development of their digital infrastructures and make efforts connected to their interoperability and mitigation of cyber risks.

Looking at it from a policy standpoint, the state and regulatory authorities should create an atmosphere conducive to embracing digital technology, ensuring the required standards and quality assurance processes are in place. The application of digital health initiatives into accreditation systems, such as NABH and setting them up in line with the global patient safety goals, will lead to more significant accountability and compliance. Further research and institutional initiatives should pay more attention to implementing artificial intelligence, machine learning, predictive

analytics, and smart surveillance technologies into the medication safety policies, while ensuring the multidisciplinary and international cooperation is brought to a new level when it comes to the implementation of digital technologies.

## AUTHOR DECLARATIONS

**CRediT Author Statement / Author contributions**

**Hurrin Zia:** Conceptualization; Writing – Original Draft; Visualization.

**Samiyah Khan:** Conceptualization; Writing – Review & Editing.

**Bhupinder Chaudhary:** Supervision

**Ishrat Rasool:** Methodology; Formal Analysis.

**Acknowledgement:** The authors would like to state that no specific funding or support was received for this study.

**Conflict of Interest**: The author(s) declare no conflicts of interest.

**AI Statement:** The authors used Grammarly exclusively as a proofreading tool to enhance language precision and sentence structure. The core ideas, interpretations, and written content remain fully the original work of the authors.

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**How to cite**: Zia, H., Khan, S., Chaudhary, B., & Rasool, I. (2025). Digital transformation in medication safety: A systematic and bibliometric analysis of high-alert medication management in healthcare settings. *Sports, Health & Wellness Insights*, *1*(2), 51–64. https://doi.org/10.64006/shwi/1205