International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 7 Issue 8, August - 2023, Pages: 12-19

Artificial Intelligence and Information Technology for Clinical Decision Support for Reducing Hospital-Acquired Conditions and Improving Patient Outcomes: A Systematic Literature Review

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Abstract— *The United States healthcare payment model has shifted from a fee-for-service healthcare approach to a more quality-driven system. As more financial metrics for compensation are tied to quality, healthcare organizations are looking for ways to improve quality while still containing costs. Understanding and studying the potential of artificial intelligence might be critical to providing safety and quality patient care. Additionally, data-driven artificial intelligence may be cost-effective and could reduce some hospital-acquired pressure injuries. The systematic literature review aimed to determine whether using artificial intelligence and information technology tools for clinical decision support and guidance during hospital admissions helps reduce or minimize hospital-acquired conditions while improving patient outcomes. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses, a literature search transpired utilizing Public Medline and Cumulative Index to Nursing and Allied Health Literature. Data from the 23 germane articles were extensively analyzed using screening criteria focused on the research question. Four themes came to the forefront during the data examination process. These themes included (a) artificial intelligence, information technology, and machine learning tools, (b) clinical decision support systems, (c) hospital-acquired conditions and infections, and (d) improved patient outcomes. The findings indicated substantial potential for using artificial intelligence to help reduce hospital-acquired conditions and enhance patient outcomes. Since the technology is applied so infrequently, there is no definitive answer to using artificial intelligence to help reduce hospital-acquired conditions and infection; the implications of these findings provide health and informatics leaders, along with researchers, an opportunity to further develop and implement artificial intelligence within clinical decision support systems to help reduce hospital-acquired conditions and improve patient outcomes.*

Keywords— Artificial Intelligence; Clinical Decision Support Systems; Hospital Acquired Conditions

1. INTRODUCTION

Artificial intelligence (AI) is an ever-expanding field, and its application has started to be utilized in healthcare. Some AI technologies are being implemented and studied to help improve patient outcomes. Artificial Intelligence is currently used to identify hospital-acquired infection (HAI) determinants and predict their occurrence within patients [16]. According to Wu et al. (2021), artificial intelligence implementation within clinical decision-making has already been introduced in specific environments, with an early emphasis on Sepsis identification [8]. Hospital acquired conditions/infections (HACs/HAIs), can negatively impact a patient's health outcome, with studies showing that the length of stay for patients with at least one adverse event was, on average, 5+ days longer than a patient without any adverse events [17]. However, it remains to be seen if utilizing artificial intelligence and information technology tools for clinical decision support and guidance during hospital admissions helps reduce or minimize hospital-acquired conditions and improve patient outcomes.

A significant challenge exists within the healthcare system to reduce and prevent hospital-acquired conditions within a clinical setting. Toffaha et al. (2023) stated that at least one in every twenty hospital patients suffered an avoidable injury, while 12% suffered a permanent disability or died due to injury [5]. Several authors have observed that utilizing machine learning or artificial intelligence and information technology application for clinical decision support might reduce or prevent HACs and increase patient outcomes (Liu et al., 2023; Brufau et al., 2020). However, some scholars believe that artificial intelligence has flaws for many reasons, including technological maturity (Wu et al., 2021), and machine "hallucination" (Lieu et al. 2023). This systematic literature review explores whether utilizing artificial intelligence and information technology tools for clinical decision support and guidance during hospital admissions helps reduce or minimize hospital-acquired conditions while improving patient outcomes.

2. METHODS

After referencing Google Scholar to help refine a research topic choice, we chose articles directly related to answering the research question; "Does utilizing artificial intelligence and information technology tools for clinical decision support and guidance during hospital admissions help reduce or minimize hospital-acquired conditions/infections while improving patient outcomes?" A

search of the literature transpired utilizing Pubmed and CINAHL while excluding MEDLINE queries and databases following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009). These method phases included (a) searching for relevant studies, (b) screening for inclusion and exclusion criteria, (c) data extraction based on the screening criteria, (d) synthesis of the data to identify key themes, and (e) reporting and dissemination of the findings (Page et al., 2021). Searching the academic databases utilizing keywords, *AI applications in clinical decision support, and reducing hospital-acquired conditions* provided consistent parameters in screening the best articles to review the topic and answer the research question.

2.1 Inclusion Criteria

The inclusion criteria of articles to review, publications had to meet the following criteria, (a) publication dates between 2019 and 2023, (b) written in English, (c) published peer-reviewed journal articles, (d) free full-text articles, and (e), with a focus on utilizing artificial intelligence and information technology tools for clinical decision support and guidance during hospital admissions to help reduce or minimize hospital-acquired conditions/infections while improving patient outcomes. The first academic database Pubmed (Medline), resulted in 175 articles, and when the applied filters were in place, the number was reduced to 45. The second academic database Cumulative Index to Nursing and Allied Health Literature (CINAHL) resulted in 46,722 articles, and when the applied filters were in place, the number decreased to 5 (see Fig 1.). This review excludes any articles that do not meet the inclusion criteria. The final total was 23 articles.

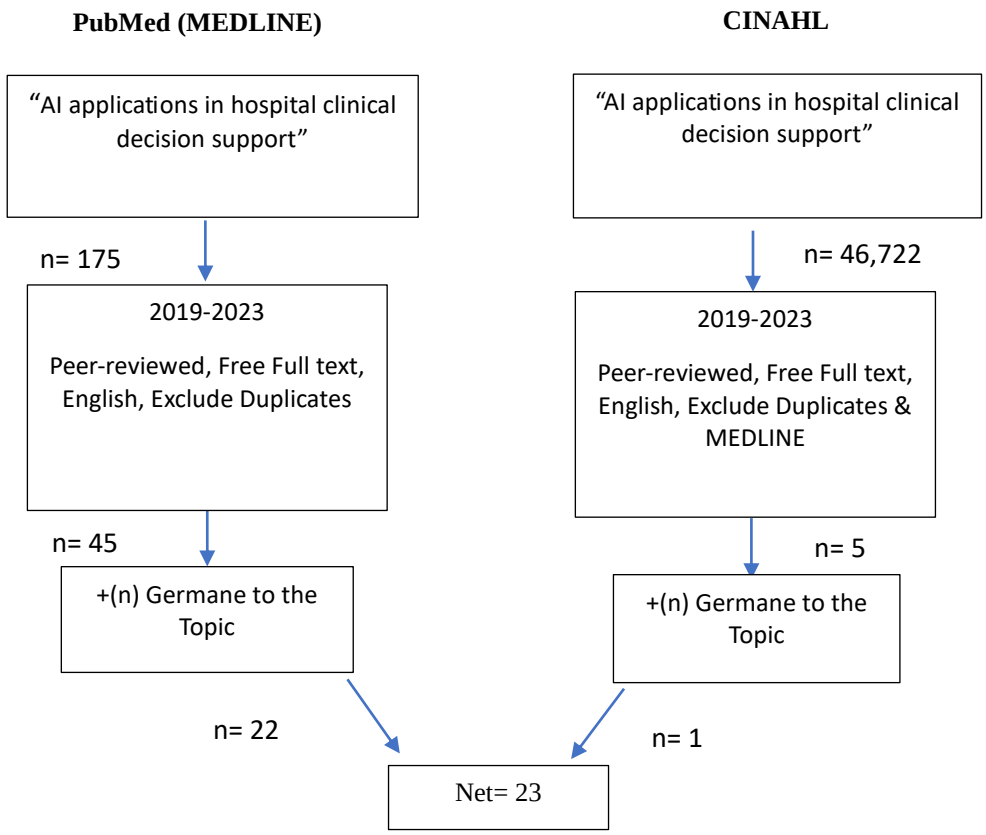

Fig.1. *Article Inclusion Criteria*

2.2 Kappa Calculation

In calculating Kappa calculation, we started with 51 articles identified and reviewed by two independent reviewers; the kappa coefficient transpired using the kappa coefficient guidelines of (a) 0 = none, (b) .01-.2 slight, (c).21-.40 fair, (d) .41-.60 moderate, (e) .60-.80 substantial, and (f) .80-1 almost perfect, (McHugh, 2012). The Kappa analysis results for this review displayed Kappa calculated at 0.841 (see Fig 2.). The articles evaluated by two independent researchers demonstrated an almost perfect agreement that exceeds the expectation of solely chance.

		Reviewer 2		
		Yes = 1	No = 0	Total
Reviewer 1	Yes	23	4	28
	No	0	23	23
	Total	23	27	51

Fig.2. *Kappa Calculation*

3. RESULTS

The research question addressed in the study was, does utilizing artificial intelligence and information technology tools for clinical decision support and guidance during hospital admissions help reduce or minimize hospital-acquired conditions while improving patient outcomes? An extensive literature inquiry and review was performed using two academic electronic databases, Public Medline and Medical Literature Analysis and Retrieval System Online [PubMed (MEDLINE)]and Cumulative Index to Nursing and Allied Health Literature (CINAHL). The literature search, selection, and data analysis used the process described in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021).

After thoroughly searching PubMed (MEDLINE)] and CINAHL, it yielded 46,897 studies. Based on the data reviewed from 46,897 studies chosen, 23 articles were germane to the research question. The ultimate decision to use these studies transpired by evaluating and finalizing the summary of findings from each article (see Table 1). After meticulously evaluating the summary findings, one additional article was excluded from the study. Table 1 lists the title of the articles and a summary of key findings from these 23 articles.

Table 1: Summarized findings of the literature.

Title	Findings
[1] The role of electronic health record and "add-on" clinical decision support systems to enhance antimicrobial stewardship programs	Utilizing various EHR add-ons and clinical decision support systems can help organizations collect antimicrobial data, prompting interventions and help with resistance tracking among microbial diseases. The article explains how various tools can help determine if ongoing treatment is needed, especially during the long term. Lists 5 critical areas for daily interventions, goes into depth on what these areas are and how they benefit CDSSs. Closes with potential future needs from a systems perspective.
[2] Artificial Intelligence in Clinical Decision Support: Challenges for Evaluating AI and Practical Implications	Demonstrates the present role of AI in supporting clinical decisions. Highlights benefits and potential risks to patients and the care provided, as well as the necessity for AI to be implemented responsibly and effectively into clinical decision-making.
[3] Using AI-generated suggestions from ChatGPT to optimize clinical decision support	Discusses whether AI-generated suggestions are meaningful in various aspects around CDSSs. These suggestions can include various medications, alerts, vaccines for types of patients, and much more, which HCPs evaluated. This could lay the foundation for AI to be more prevalent in clinical settings, as most suggestions were rated on average 3.3 (plus/minus 0.5). AI-Generated suggestions provided additional immunosuppressive medications and treatments and excluded additional patients.
[4] A retrospective study on the effectiveness of Artificial Intelligence-based Clinical Decision Support System (AI-CDSS) to improve the incidence of hospital-related venous thromboembolism (VTE)	Discuss whether AI-CDSS can help clinicians identify patients with an increased risk of venous thromboembolism (VTE). VTE mainly occurs during hospitalization or shortly after discharge; incidence after AI CDSS dropped by 19.35%, with evidence-based educational programs increasing prophylaxis by physicians. Due to increased detection, anticoagulant drugs increased by 14.57%.
[5] Leveraging artificial intelligence and decision support systems in hospital-acquired pressure injuries prediction: A comprehensive review	Learning artificial intelligence can help reduce medical errors, including transfusion, incorrect diagnosis, under/over treatment and more. The article uses 3 scales that are used to identify patients with predicting pressure ulcers within various patient populations. Additionally touches on the limitations of current versions of artificial intelligence and what is needed for the future.

[6] Preventing sepsis; how can artificial intelligence inform the clinical decision-making process? A systematic review	Utilizing AI to prevent sepsis within CDSS, including AI reviewing identified predictors. Discusses how artificial intelligence can help predict diseases and is a better predictive method than current systems.
[7] Artificial Intelligence for Clinical Decision Support in Sepsis	Implementing AI to help prevent sepsis, including predicting, diagnosis, sub-phenotyping, prognosis assessment, and clinical management. Touches on the beginning of artificial intelligence in 1956 at Dartmouth Conference. Goes in-depth into an early prediction of sepsis, septic shock, improving accuracy of Sepsis diagnosis, and risk assessment of Sepsis.
[8] Development and initial implementation of electronic clinical decision supports for recognition and management of hospital-acquired acute kidney injury.	Authors developed and evaluated content, acceptability and usability of electronic clinical decision support tools for Acute Kidney Injury (AKI) care. Various systems were implemented to help with the treatment of AKI patients was designed by a team with diverse medical backgrounds.
[9] Implementation of Artificial Intelligence-Based Clinical Decision Support to Reduce Hospital Readmissions at a Regional Hospital	AI tool was implemented to assess all patients admitted to general units for risk of readmission and recommendations for interventions to decrease readmission risk also obtained information straight from the EHR. Article measures all-cause readmission rates, rather than just preventable readmission rates.
[10] Machine Learning Approach to Reduce Alert Fatigue Using a Disease Medication–Related Clinical Decision Support System: Model Development and Validation	Article discusses the development and implementation of machine learning prediction models to predict physicians' responses to reduce alert fatigue. Some tools provided insight into potential features that could be implemented ino system design and provide a provider friendly interface that could help reduce alert fatigue and preventable errors in care.
[11] Explainable Artificial Intelligence for Predicting Hospital-Acquired Pressure Injuries in COVID-19–Positive Critical Care Patients	Article evaluated Hospital Acquired Pressure Injuries in COVID 19 positive critical patients, & machine learning models to predict risk and apply relevant AI for model transparency and human comprehension. AI were also able to identify the most important factors and the correlation between these factors and potential HAI acquisition.
[12] mHealth apps for gestational diabetes mellitus that provide clinical decision support or artificial intelligence: A scoping review	Reviews various literature and types of AI that were utilized in mHealth apps. Also discusses how few of the AI were mature enough to be used within a clinical setting and that no single app targeted the entirety from diagnosis to postpartum.
[13] Developing an AI-assisted clinical decision support system to enhance in-patient holistic healthcare.	Reviews data of patient predictions and identification for holistic health care by AI-supported CDSSs. This can improve patient outcomes as the AI attempts to understand their various care needs and aspects of their care, including physical, emotional, social, economic, and spiritual.
[14] Supporting Hospitalized Patients through AI Technologies	Utilizing AI to help patients remember various health information and care information along with retention of such information
[15] The Use of Artificial Intelligence and Machine Learning in Clinical Research and Health Care	Discusses types of AI and ML, along with their potential applications. Additionally, discusses the potential for predictive modeling and nanotechnology for various types of diseases and improving patient outcomes.
[16] Artificial Intelligence in Clinical Decision Support: Challenges for Evaluating AI and Practical Implications	Discusses challenges of AI, requirements for AI to succeed, as well as what AI could potentially improve within healthcare and its implications
[17] Artificial Intelligence and Surgical Decision-Making	Discusses current challenges revolving around surgical decision-making and how AI, machine learning, and deep learning can help enhance the surgical experience for patients.
[18] Interpretability of Clinical Decision Support Systems Based on Artificial Intelligence from Technological and Medical Perspective: A Systematic Review	Reviewing different types of AI, the current interpretation methods in CDSSs, and artificial intelligence. Also discusses what types of data are used for Artificial Intelligence decision-making, how interfaces impact user experience and understanding, and the logic behind artificial intelligence with healthcare data.

[19] Artificial intelligence-based clinical decision support in pediatrics	Discusses AI and how it can potentially overcome some of the current limitations attributed to traditional CDSSs, and how the AI CDS systems generate their methods. Discusses what diseases AI models have been used to identify/predict in the past.
[20] Artificial intelligence in intensive care: moving towards clinical decision support systems	Discuss what will be needed for AI implementation within CDSSs, how and what data is collected, and what potential deterrents will be present. Discusses what AI could potentially improve within an ICU setting for patients and physicians.
[21] Impact of Data Presentation on Physician Performance Utilizing Artificial Intelligence-Based Computer-Aided Diagnosis and Decision Support Systems	Discusses incorporating AI based decision support tools to improve reader workflow and its impact on clinical performance, impacting patient care
[22] Machine learning for clinical decision support in infectious diseases: a narrative review of current applications	Discusses the utilization of AI in clinical settings, the outcomes in ICUs, and the various predictions and results within those settings of various HACs (sepsis etc.)
[23] Artificial Intelligence in Clinical Decision Support: a Focused Literature Survey	Discusses current issues with AI and transparency issues regarding how the AI reaches a conclusion. Also reviews what types of AI are being utilized within clinical DSSs, and central themes revolving around AI research.

The information retrieved from the 23 articles connects to categorizing the rate of occurrence regarding artificial intelligence/information technology tools and clinical decision support systems concerning hospital-acquired conditions/infections and improving patient outcomes, which resulted in four main themes (see Table 2). Each theme directly relates to the research question presented. The following themes included: (a) artificial intelligence/information technology/machine learning tools, (b) clinical decision support systems, (c) hospital-acquired conditions/infections, and (d) improved patient outcomes.

Table 2: Frequency of occurrence in the literature.

Theme	Occurrences	Instances of Attributes (n)	Percentage (%)
Theme 1: Artificial Intelligence (AI)/Information Technology (IT) Tools/Machine Learning	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	22	96%
Theme 2: Clinical Decision Support Systems (CDSSs)/Decision Support Systems	1,2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21, 22, 23	22	96%
Theme 3: Hospital-Acquired Conditions/Infections (HAC/HAI)	4, 5, 6, 8, 11	5	22%
Theme 4: Improved Patient Outcomes	2, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16, 17, 19, 23	14	61%

From the research results, 96% (22/23) of the articles provided information on theme one, artificial intelligence/information technology (IT) tools/machine learning, comprising all the articles except eight. From the findings, 96% (22/23) of the articles addressed theme two, clinical decision support systems/decision support systems, which only excluded article fourteen. The results show that 22% (5/23) of the articles exhibited theme three, hospital-acquired conditions/infections (HAC/HAI), which includes articles 4, 5, 6, 8, and 11. Finally, the findings displayed that 61% of the articles mentioned theme four improve patient outcomes, which includes articles 2, 5-10, 12, 14-17, 19, and 23.

4. Discussion

This systematic literature review aimed to determine whether utilizing artificial intelligence and information technology tools for clinical decision support and guidance during hospital admissions helps reduce or minimize hospital-acquired conditions while improving patient outcomes. Twenty- three peer-reviewed articles that were published between 2019 through 2023 were analyzed for the study, which allowed for a current analysis of artificial intelligence (AI)/information technology (IT) tools/machine learning, clinical decision support systems (CDSSs)/ decision support systems, hospital-acquired conditions/infections (HAC/HAI), improved patient outcomes. The data results shown in Table 2 display the prevalent themes from the literature analysis. Four main themes emerged from the literature analysis that included AI/IT tools/machine learning (1-7, 9-23), CDSSs/decision support systems (1-13, 15-23), HAC/HAI (4-6, 8, 11), improved patient outcomes (2, 5-10, 12, 14-17, 19, 23).

Theme one produced data on AI/IT tools/machine learning, which was demonstrated by 96% of the articles in the literature review [1-7,9-23] Zhou et al. discovered that AI-enabled CDSS can aid physicians in identifying hospitalized patients with an increased risk of hospital-related Venous Thromboembolism (VTE). However, Magrabi et al. stated that AI could affect aspects such as resource management and prioritization, which could increase the risk of bias in care, which must be carefully and thoroughly considered. Furthermore Montani et al. found that the possibility of AI reaching beyond human comprehension is a real possibility. While humans can build and develop such technology, understanding the true outcomes and consequences may be much more difficult. Due to this, a more thorough understanding of how AI can impact healthcare is required.

Theme two produced data on CDSSs/decision support systems, highlighted by 96% of the articles in the literature review. [1-13, 15-23] Juang et al. stated that their AI-assisted CDSS could outperform the traditional criteria-based expert-specified approach. However, Ramgopal et al. stated that most limitations that apply to traditional CDS system implementations also apply to AI CDS systems, as some physicians are resistant to specific prompts when the prompts are viewed as enforcement, not as a choice, which could hinder implementation within a clinical setting. Furthermore, Montomoli et al. suggested a Clinical Artificial Intelligence Departments (CAID) to help facilitate AI CDSS to all caregivers, physicians, hospitals, ambulatories etc [21]. Additional research across different specialties and health systems is needed to understand how to overcome these limitations.

Theme three produced data on hospital-acquired conditions/infections, demonstrated in a lower percentage of articles at 22 percent. [4-6, 8, 11] Toffaha et al. discovered that using artificial intelligence and clinical decision support systems can help reduce the various hospital-acquired pressure injury (HAPI) risks, which is done through proactive identification of risk factors for various patients.[5] However, Toffaha et al. also stated that there are still potential issues revolving around data accuracy that can limit the reliability of predictive HAPI identification [5]. Additionally, Loftus et al. found that data standardization must be designed and implemented if the implementation of AI models with any AI, within every setting, is going to be feasible [18]. As a result, more studies are needed to determine more accurately what can be implemented to help improve the timely identification of hospital-acquired conditions/infections.

Theme four generated data on improving patient outcomes, which was demonstrated by a percentage of 61 percent of articles. [2, 5-10, 12, 14-17, 19, 23] Ramgopal et al. found that a properly implemented AI-assisted CDS tool could enable care providers to provide improved patient care at the bedside, enhancing the patient experience. In contrast, Magrabi et al. found that if AI is going to impact patient outcomes positively, however, AI developers must be transparent regarding the ethical limitations of AI to ensure quality care is provided to all patients. Additionally, Wu et al. stated concerns regarding the current lack of ethical and safety guidelines within current AI technologies, as this could inflict more harm than good if left unchecked.

4.1 Limitations

Notwithstanding the findings stated, the review had certain limitations. The review took place over 12 weeks. The exclusion of non-English language articles may have prevented publications from participating in the study. After completing a preliminary search in Google Scholar for the literature review, PubMed and CINAHL academic databases were utilized to search for peer-reviewed journal articles. keywords were used to help guide the search process; however, alternative terminology may exist that yields additional articles in the academic databases for the review. A limitation of the study is the subjective nature of the article reviewer, which may permit different interpretations of the findings.

4.2 Mitigating Limiations

These limitations were mitigated by adhering to the PRISMA-based systematic review practices (Page et al., 2021). We utilized multiple sources to filter the information collected, starting with 175 articles from PubMed, and 46,722 articles from CINAHL, until a saturation point of the literature occurred, and no additional information was available for the developing themes. Even though the

study had possible limitations, the findings indicated substantial potential for using AI to help reduce HACs and improve patient outcomes; however, such technology is so infrequent that there is no definitive answer currently.

5. CONCLUSION

Over the past decade, we have seen a gradual shift in healthcare technology adoption, along with financial incentives for these adoptions. Artificial intelligence has been found to help reduce the risks of hospital-acquired pressure injuries [5] and enable providers to provide improved bedside patient care [20]. It was unclear whether artificial intelligence implementation could help reduce hospital-acquired conditions while improving patient outcomes. Implementing artificial intelligence has been found to help physicians identify hospitalized patients with an increased risk of hospital-related Venous Thromboembolism (VTE) [4]. This systematic literature review aspired to determine whether implementing AI in clinical decision support systems can help reduce hospital-acquired conditions while improving patient outcomes. While analyzing the data, four themes emerged from the research: (a) artificial intelligence, information technology, and machine learning tools, (b) clinical decision support systems, (c) hospital-acquired conditions and infections; and (d) improved patient outcomes. Due to the results of this literature review, the implementation of artificial intelligence within clinical decision support systems has great potential to impact patient outcomes positively. Further research on this topic can include financial impact for the organization and the patients and a more comprehensive review of AI's impact on HACs/HAIs. The results of this review highlight an opportunity for researchers and healthcare leaders to further develop and implement AI within CDSSs to help reduce HACs and improve patient outcomes.

5.1 FUTURE IMPLICATIONS

The review's findings can serve as a foundation to build upon for future researchers incorporating a more comprehensive research method or design that integrates qualitative interviews and quantitative surveys to provide additional insights into the research topic and question. These findings offer healthcare leaders information to take action and develop procedures and policies more concertedly to understand the potential impact of artificial intelligence on patient outcomes. The results indicated a substantial potential for artificial intelligence to impact patient outcomes positively. Scholars may consider narrowing or broadening the focus of the study to enable a more in-depth exploration of specific aspects related to employing artificial intelligence and information technology tools for clinical decision support and guidance in hospitals. A final recommendation to other upcoming researchers is to collaborate with other leaders in the research from varying healthcare specialties to aid in reducing or minimizing hospital-acquired conditions while improving patient outcomes.

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