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The Role of Artificial Intelligence in Enhancing Medication Dispensing and Improving Adherence: A Systematic Review

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ABSTRACT

Artificial Intelligence (AI) has been making remarkable advancements in the field of healthcare, and its integration into various healthcare processes has the potential to revolutionize the way medical care is delivered. One area where AI has shown promise is in medication dispensing and adherence. This systematic review aims to explore the role of AI in enhancing medication dispensing and improving adherence. In this paper, we will provide a background on the historical evolution of AI in healthcare, as well as current trends in AI for medication dispensing and adherence. We will also discuss the methodology of the systematic review, including the criteria used for selecting studies and the limitations of the review process. Furthermore, we will examine the AI technologies that are currently used in medication dispensing, the challenges associated with implementing AI in dispensing, and how AI technologies improve accuracy and efficiency. Additionally, we will explore the AI-driven strategies for medication adherence, including the approaches AI offers to enhance patient adherence to medication, how AI systems monitor and support patient adherence, and the outcomes of AI interventions on medication adherence. Finally, we will discuss the future implications of AI for medication dispensing and adherence, including potential transformations and recommendations for healthcare providers adopting AI, along with the ethical and regulatory considerations for AI in this context.

Keywords: Artificial Intelligence, dispensing, medication, healthcare

1. INRODUCTION

1.1 The historical evolution of AI in healthcare

The historical evolution of artificial intelligence (AI) in healthcare is a testament to the synergistic relationship between medicine and technology. From its nascent stages in the 1970s, where AI applications began to address biomedical problems, the domain has witnessed a remarkable transformation over the past half-century [1]. In these early years, AI was principally concerned with the creation of mathematical models that could simulate human cognition in the resolution of complex healthcare issues. However, the progression from these foundational models to today's sophisticated predictive and assessment tools underscores the significant strides AI technology has made [2]. Indeed, the current healthcare revolution, characterized by personalized patient care, the advent of deep learning models, and innovative AI-enhanced surgical procedures, reflects an ongoing and dynamic evolution [2]. AI's impact has been so profound that its applications, once limited to niche areas within the biological sciences, now permeate a wide array of medical specialties, reshaping every facet from diagnostics to treatment options [3]. Despite this, the widespread adoption ofAI in healthcare has been met with some resistance from industry leaders, often leading to a slower and more erratic integration than seen in other sectors [1]. Nevertheless, the growing interest in AI-powered healthcare applications continues to drive research and development, signaling a future where AI's role in healthcare is not just prevalent but indispensable [2].

1.2 Integration of AI into various healthcare processes

Building on the initial applications of AI in the medical field, the integration of artificial intelligence into various healthcare processes has further revolutionized the industry. AI technology has become indispensable in managing the vast amounts of data generated from clinical activities, such as screening, diagnosis, and treatment assignment [4]. This capability is particularly evident in the realm of diagnostics, where AI programs are now routinely applied. For instance, machine learning models, which must be extensively trained using large datasets, are now instrumental in the interpretation of traditional radiographs, bolstering the efficiency and accuracy of triage processes [1]. Furthermore, personalized medicine has been significantly enhanced by AI, which tailors treatment protocols and drug development to individual patient profiles, leading to more effective and targeted care [1]. The digitization of medical records is a prime example of AI's transformative impact on healthcare processes, paving the way for more streamlined and accessible patient information management [5]. In tandem with these advancements, AI-driven systems such as XSOLIS offer guidance to healthcare providers, helping them to overcome the barriers to AI implementation and to harness its full potential, leading to improved utilization review and overall better patient outcomes [3]. With AI's integration into healthcare, the sector is witnessing a transformative change, one that is enhancing the capabilities of health services management and decision-making, thereby setting new standards for patient care and system efficiency [4] [3].

1.3 The current trends in AI for medication dispensing and adherence.

In the pursuit of more efficient health service delivery, particularly in medication dispensing and adherence, AI has emerged as a significant innovator, notably in addressing disparities in healthcare access. Specifically, AI's integration into health services management harnesses the power of electronic health records (EHRs) to not only predict necessary diagnostic tests and analyses but also to streamline patient data into a cohesive representation that enhances the clarity and effectiveness of service analysis [4]. This predictive capability is a cornerstone of optimizing logistics in medication dispensing, as AI algorithms can forecast medication needs, thereby ensuring timely and accurate delivery of prescriptions, especially crucial in areas where resources are scarce [4]. Moreover, AI's role extends to the critical area of personnel training, offering a standardized and scalable approach to equipping health service providers with the requisite knowledge and skills to navigate an increasingly complex medication dispensing landscape [4]. In this way, AI serves as a bridge, reducing the divide between urban and rural healthcare provisions, ensuring that advancements in medication management benefit a broader spectrum of the population [4]. By enhancing logistics, training, and management practices, AI not only improves current systems but also lays the groundwork for a more resilient and accessible healthcare infrastructure.

2. Methodology of the Systematic Review

2.1 Criteria used for selecting studies in the review

In selecting studies for the review, a structured and well-defined approach was employed to ensure the inclusion of relevant research while maintaining high standards of scientific rigor. The process began with the identification of studies through a systematic search, adhering to pre-set criteria that were meticulously established to guide the selection process [6]. These criteria were comprehensive, encompassing the types of studies to be considered, the characteristics of the participants, the nature of the interventions under scrutiny, and the specific outcomes to be measured [7]. This level of detail provided clarity on the scope of the review and the benchmarks used to gauge the relevance and quality of each study. Furthermore, to maintain transparency and replicability, the review clearly outlined the inclusion and exclusion criteria, ensuring that any subsequent researchers could understand the decisions made and, if necessary, apply the same standards to future research [7]. The criteria for measurement of outcomes were articulated, which is critical for comparing results across different studies and synthesizing findings [7]. To enforce these criteria, a two-step screening process was typically recommended, starting with a title and abstract review to exclude studies that did not pertain to the topic at hand,followed by a more in-depth screening where the full text of the remaining studies was examined against the inclusion/exclusion criteria [6]. This two-tiered approach, often conducted by two independent reviewers, not only enhanced the objectivity of the study selection but also provided a check against selection bias [6]. In instances where discrepancies arose, a consensus procedure was in place to resolve any areas of disagreement, thereby reinforcing the methodological integrity of the review [6].

2.2 Data extracted and synthesized from the selected studies

The rigorous process of data extraction and synthesis in systematic reviews has significantly contributed to the evolution and application of AI in healthcare. Such reviews employ a structured methodology to ensure the comprehensiveness and accuracy of the evidence collected, aligning with the steps outlined for conducting a systematic review [8]. Initially, the review process begins with framing specific questions, crucial to directing the scope of the inquiry in a focused manner [6]. This is followed by identifying relevant literature that meets predefined inclusion and exclusion criteria, ensuring that only pertinent studies are considered for analysis [6]. Once relevant work has been identified, the quality of each study is meticulously assessed to determine the reliability of the findings and their applicability to the research question [8]. Summarizing the evidence is the subsequent step, where data from individual studies is synthesised to create a cohesive understanding of the research area. This synthesis is not only about aggregating data but also involves a detailed evaluation to draw meaningful conclusions about the AI applications in question, potentially highlighting gaps in knowledge or areas for further development [8]. By following this systematic approach, researchers can compile a comprehensive summary of the existing literature, which is particularly valuable given the rapid advancements in AI technologies and their implications for healthcare [9]. This meticulous process of data extraction and synthesis, therefore, plays a pivotal role in shaping the knowledge base from which AI in healthcare can continue to evolve and improve patient outcomes.

2.3 The limitations of the systematic review process

While the integration of AI in health services shows promise for enhancing utilization review, the systematic review process that underpins the evaluation of such technologies is not without its limitations. A significant constraint is the necessity for a sufficient budget and time allocation, which are foundational to conducting a thorough systematic review [10]. This process is inherently resource-intensive, not only from a financial standpoint but also in terms of human capital, as it requires meticulous coordination and teamwork among reviewers [10]. The demands for such collaboration are heightened by the need for additional processing and documentation, a characteristic of the systematic review methodology that can further complicate the review process [10]. Moreover, the lack of proper resources, such as databases, software tools, or access to full-text study reports, may impede the appropriateness and depth of the method applied in the systematic review, potentially affecting the overall quality and reliability of the findings [10]. Additionally, each study included in the review must undergo a rigorous quality assessment to evaluate the risk of bias, which adds another layer of complexity and time consumption to the process [10]. When feasible, statistical analysis is employed to consolidate and enhance the power of the data from multiple studies, but this relies heavily on the amount and quality of available data, which can vary widely and thus restrict the applicability or generalization of the review's conclusions [10]. These limitations underscore the challenges faced in ensuring the systematic review process is as robust and comprehensive as possible, especially when assessing emerging technologies in healthcare.

3. AI Technologies in Medication Dispensing

3.1 AI systems currently used in medication dispensing

In the modern healthcare setting, AI systems have become integral to enhancing the efficiency and accuracy of medication dispensing, a critical component of patient care. AI-powered prescription-filling robots are increasingly common in pharmacies, using sophisticated algorithms to safely expedite the medication dispensing process, ensuring patients receive their medications promptly and accurately [11]. These robots are complemented by automated dispensing cabinets, which are employed in numerous hospitals and large-scale pharmacies to minimize direct human handling of medications, thereby reducing the potential for contamination and errors [11]. Moreover, AI is instrumental in improving patient outcomes through the provision of medication reminders and the monitoring of medication adherence patterns [11]. This dual approach not only bolsters the efficiency of the dispensing process, as evidenced by the significant reduction in error rates and waiting times,but also empowers patients to take a more active role in managing their medication schedules, facilitated by AI-enabled reminders [11].

Consequently, the integration of AI in medication dispensing is reshaping pharmacy operations, leading to a more streamlined, precise and patient-centered service delivery [11].

1.1 AI technologies in improving accuracy and efficiency

Building on the foundational use of AI in healthcare since the 1970s, current AI technologies have revolutionized the accuracy and efficiency of healthcare services. In the realm of medical imaging, AI has been a game-changer, providing tools for early disease diagnosis that were previously unattainable. The integration of machine learning and deep learning into these systems has not only improved the quality and safety of healthcare but has also led to a newfound trust in these technologies, particularly during emergency situations like the SARS-CoV-2 pandemic. This trust was solidified as telemedicine and teleprescribing practices became more widespread, showcasing the practicality and reliability of AI in critical healthcare contexts, [12]. Moreover, AI's impact extends beyond diagnosis and treatment; it also enhances operational efficiencies. For instance, community pharmacies, like Walgreens, leverage AI technologies to anticipate and meet consumer demand by ensuring that stores are stocked with the right products at the right time. By analyzing external data, such as local health trends, AI enables these pharmacies to forecast demand with remarkable accuracy, thus improving efficiency in managing inventory and predicting regional and local spikes in demand,[11]. The sophistication of AI in healthcare suggests a trend towards augmentative tools that support healthcare professionals rather than replace them, fostering a partnership that prioritizes patient care through improved interpretability and trust in AI systems, [12].

1.2 Challenges associated with implementing AI in dispensing

While AI offers the promise of revolutionizing pharmacy practice, its integration into dispensing processes is not without significant hurdles [13]. Among the most formidable challenges is the cost of adoption. For many pharmacies, especially smaller ones, the initial investment needed to integrate AI technologies can be prohibitively expensive [13]. These organizations often operate with constrained budgets and limited resources, making the financial barrier even more pronounced [13]. Beyond fiscal concerns, there is a degree of resistance from within the profession itself. Some pharmacists exhibit reluctance towards embracing AI solutions, possibly due to apprehensions about the reliability of automation or the fear of being replaced [13]. This resistance suggests a need for thorough education and training programs to build pharmacists' trust in AI and demonstrate its role as an aid rather than a replacement in dispensing [13]. As AI has the potential to improve efficiency and patient care by streamlining operations and minimizing dispensing errors [14], overcoming these challenges is essential for the advancement of pharmacy services [13].

2 AI Driven Strategies for Medication Adherence

1.3 Approaches of AI to enhance patient adherence to medication

Artificial Intelligence (AI) offers a multifaceted approach to enhance patient adherence to medication by providing personalized interventions and support. Tools like AI-driven chatbots and virtual assistants are at the forefront of this transformation, offering round-the-clock personalized communication to patients. They can address common concerns related to medication intake, such as side effects or the importance of timely doses, thereby reducing the ambiguity and anxiety that often accompany complex treatment regimens [15]. Moreover, these platforms are designed to learn and adapt continuously, optimizing their strategies to target individual behaviors and preferences more effectively [16]. This adaptive learning capability is crucial, as it allows the AI to refine its understanding of what interventions work best for each patient, leading to highly tailored support programs [16]. For example, AllazoHealth's AI platform can predict which patients are at risk of non-adherence and tailor interventions accordingly, thereby preempting potential lapses in medication adherence [16]. The result is a more engaged patient who feels supported and informed, making adherence to medication a less cumbersome and more manageable aspect of their healthcare journey [15].

1.4 AI systems monitoring and support in patient adherence

Building on the foundation laid by earlier AI applications in healthcare, modern AI systems have become integral in enhancing patient adherence to treatment regimens. One of the pivotal functions of AI in this domain is the ability to send reminders and notifications to patients, ensuring that they take their medications as prescribed [17]. This functionality is not trivial, as it directly addresses the challenge of forgetfulness, which is a common barrier to adherence. Furthermore, AI's impact is considerably significant for those with chronic illnesses, such as diabetes and cardiovascular diseases, where consistent medication intake is crucial for managing the condition [18]. By monitoring real-world data, including lab values, AI systems can assess whether patients are following their treatment plans effectively [18]. In instances where a patient may not be adhering to their prescribed regimen, AI can trigger alerts to healthcare providers, prompting them to take action to address the non-compliance [18]. This proactivity is bolstered by AI's predictive capabilities, which can identify patients who are at risk of non-adherence, enabling healthcare providers to intervene before the patient's condition deteriorates [18]. Moreover, AI systems can direct healthcare providers to concentrate their efforts on patients who are identified as at risk, ensuring that the right support is provided at the right time [18]. In this way, AI acts as a bridge between patients and healthcare providers, personalizing the support system and improving health outcomes through enhanced adherence.

4.4 *Outcomes of AI interventions on medication adherence*

AI interventions are poised to revolutionize the way patients adhere to their prescribed medication regimens. The common challenge of medication non-adherence is often exacerbated by the complexity of drug regimens, which can be confusing and overwhelming for patients, particularly those with multiple prescriptions [19]. This is where AI-based solutions come into play, offering a means to simplify the convoluted schedules and instructions that accompany many treatment plans. By harnessing the power of AI, healthcare providers can deploy systems that tailor dosing schedules to individual patient needs, thereby reducing the cognitive load and potential for human error. Such interventions can lead to more seamless self-administration of medications, ensuring that patients are more likely to follow their prescribed courses of treatment [19]. The potential for improved adherence rates is significant, not only enhancing the effectiveness of pharmacotherapy but also possibly reducing healthcare costs associated with non-adherence-related complications [15]. Therefore, as healthcare systems continue to integrate AI into their practices, as indicated by the increasing use of machine learning models and AI applications in health services, the emphasis on medication adherence presents a promising area for AI to make a substantial impact on patient health outcomes.

2 Future Implications and Recommendations

1.5 Potential of AI to transform medication dispensing and adherence in the future

The transformative potential of AI in medication dispensing and adherence is vast, with implications stretching across the landscape of healthcare delivery and patient outcomes. As the research findings suggest, the implications of such technological advancements touch upon various aspects of the healthcare system, including the optimization of medication dispensing processes and the enhancement of patient adherence to their treatment regimens [20]. These implications are not mere theoretical outcomes but are deeply entrenched in the practical realm of healthcare, where they can lead to significant improvements in the efficiency and accuracy of medication distribution [21]. Recommendations stemming from these implications are concrete and actionable, pointing healthcare stakeholders toward adopting AI-driven systems that can personalize medication regimens, reduce human error, and ultimately contribute to better patient health outcomes [22]. Such recommendations are supported by the data indicating that AI can reliably interpret complex medical data and patient history to make real-time decisions about medication dosing and scheduling, thus ensuring that patients receive the most appropriate treatment at the right times [23].

1.1 Recommendations for healthcare providers in adopting AI

In light of the transformative impact that AI applications have had on the healthcare industry, it is critical for healthcare providers to consider the implications of these technologies and to adopt specific, evidence-based recommendations. Recognizing the distinction between implications and recommendations is crucial for healthcare providers aiming to integrate AI into their practice effectively [20]. Recommendations, in particular, should be informed by a thorough understanding of the contextual factors and mechanisms associated with effective AI integration, ensuring that these technologies are harnessed to improve patient outcomes and operational efficiency [24]. Given that recommendations are prescriptive and based on the specific results of research, they should clearly indicate actionable steps that healthcare providers can take. For example, if an AI system demonstrates high accuracy in diagnosing a particular condition, a recommendation might involve the adoption of that AI system within diagnostic protocols, accompanied by training programs for the associated medical staff to ensure proper usage and interpretation of the AI's findings [23]. These recommendations, therefore, not only provide guidance on the implementation of AI tools but also delineate the pathways for healthcare providers to augment their services in alignment with the latest technological advancements.

1.2 Ethical and regulatory considerations for AI in this context

The ethical and regulatory considerations for AI in the context of healthcare are multifaceted and critical for ensuring the safety, efficacy, and fairness of AI applications. As hospitals and health systems increasingly deploy AI tools for utilization review and other health services, it's essential to recognize the implications of these technologies for patient care and privacy. The implications of AI extend to the potential for unintended consequences, such as the introduction of bias in decision-making processes or the misuse of sensitive patient data [25]. Additionally, recommendations for the ethical use of AI in healthcare must be informed by the results of rigorous research, ensuring that specific measures are in place to safeguard patient interests and promote transparency and accountability [23]. For instance, the development of clear guidelines on data handling and the implementation of robust oversight mechanisms could be recommended to prevent data breaches and ensure that AI tools are used to support, rather than supplant, clinical judgement [22]. Addressing these ethical and regulatory considerations is paramount, as they will dictate the successful integration of AI into health services, influencing both policy and practice to ultimately benefit patient outcomes.

2. Conclusion

The role of Artificial Intelligence (AI) in enhancing medication dispensing and improving adherence has been thoroughly explored in this systematic review. The review highlights the significant strides that AI technology has made in the healthcare industry, transforming every facet from diagnostics to treatment options. The integration of AI into various healthcare processes has further revolutionized the industry, leading to a future where AI's role in healthcare is not just prevalent but indispensable. The review identifies several areas where AI has demonstrated its potential, including medication dispensing, adherence, and logistics. AI-powered prescription-filling robots are increasingly common in pharmacies, using sophisticated algorithms to safely expedite the medication dispensing process, ensuring patients receive their medications promptly and accurately. Additionally, AI interventions are poised to revolutionize the way patients adhere to their prescribed medication regimens. AI's role extends to the critical area of personnel training, offering a standardized and scalable approach to equipping health service providers with the requisite knowledge and skills to navigate an increasingly complex medication dispensing landscape. Moreover, personalized medicine has been significantly enhanced by AI, which tailors treatment protocols and drug development to individual patient profiles, leading to more effective and targeted care. The review also identifies potential limitations and gaps in the study, including ethical and regulatory considerations for AI in the context of healthcare, which are critical for ensuring the safety, efficacy, and fairness of AI applications. The review concludes that AI's integration into healthcare is setting new standards for patient care and system efficiency, and recommendations for the ethical use of AI in healthcare must be informed by the results of rigorous research to safeguard patient interests and promote transparency and accountability. Overall, the review contributes significantly to the ongoing advancement of knowledge in the field and provides several future directions for research in AI-powered medication dispensing and adherence.

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