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COMMENTARY

Artificial intelligence (AI) in pharmacy: an overview of innovations

Introduction

Pharmacies, if properly equipped, have the potential to evolve into health management centers rather than mere medication fulfillment locations[1,2]. Recent years have witnessed an exponential surge in data digitization within the pharmaceutical field[3–5]. To address complex clinical issues effectively, artificial intelligence (AI) solutions are increasingly used as part of collection, analysis, and utilization processes. AI provides an efficient means of handling vast amounts of data more effectively, with automation playing an essential part[6–8]. This technology in pharmacy practice has witnessed rapid development over the years, providing the advantages of time and cost savings, as well as simplifying various pharmaceutical tasks[9]. McKinsey Global Institute estimates that AI tools in the pharmaceutical sector may generate over $100 billion annually within the US healthcare system[10]. It is anticipated that AI tools hold immense promise to revolutionize various aspects of pharmacy practice, namely drug supply chain, safety, medication management, and patient care[11]. Chatbots can interact just like a friendly customer service representative, answering questions and helping with concerns. If there's a particularly challenging question, they can seamlessly hand it over to a human team member for a personal touch. Another example is Walgreens's partnership with telehealth firm Medline to offer patients video chats with health professionals[12]. For retail pharmacists, AI can streamline inventory management. Picture knowing in advance what medications your patients will need, stocking those items, and sending friendly reminders. AI-driven data analytics can forecast a patient's medication needs, guiding smart inventory choices[10]. Therefore, by active implementation of AI tools into pharmacy practice, pharmacists can shift their focus towards a more patient-centric approach, rather than solely concentrating on prescription dispensing[10]. They can offer more personalized healthcare services, including guidance, advice, and an expanded range of services such as immunizations, screenings, medication therapy management, and disease management[13]. Additionally, pharmacists can assist individuals in optimizing the benefits of their medications maintaining better overall health and reducing costs. Furthermore, the opportunities for collaboration with other health professionals are expected to expand when AI tools are integrated into pharmacy practice[10]. In this regard, several studies indicated a positive desire towards adopting AI technology in different healthcare domains[14–19].

However, there are several challenges that limit both the adoption and development of AI tools in pharmacy practice. Although AI tools in healthcare have gained much more attention in the last few years, only a limited number of studies highlighted the factors that hinder its adoption in pharmacy practice. Hence, this editorial aims to address various barriers to the implementation of AI into pharmacy practice in both developed and developing countries as well as suggest potential approaches to mitigate these barriers.

Discussion

As AI technology continues to revolutionize numerous healthcare sectors, it becomes imperative to tackle the obstacles that impede the implementation of AI technology in pharmacy settings. It is also crucial to devise targeted strategies that effectively address these challenges and pave the way for the seamless integration of AI technology in pharmacies in the future.

Barriers to AI integration in pharmacy practice

As is the case with any technology, AI technology could face various barriers that impede its adoption, functioning, and improvement (Table 1). The adoption of AI technology could be hindered by the lack of awareness and knowledge of AI applications in pharmacy[20]. Understanding and familiarizing pharmacists with AI technology is crucial for its successful adoption in the pharmacy field. Another important barrier to AI technology adoption is data privacy and security concerns. AI has not achieved impeccable privacy protection and safety yet AI systems carry the danger of violating patients' privacy and security since they depend on the usage of personal data to perform the required tasks[20]. The extensive data requirements of many AI models, coupled with concerns about potential data leaks, hinder the widespread adoption of AI technologies. Moreover, the integration of AI technology into the field of pharmacy can be greatly affected by regulatory constraints. Regulatory agencies typically demand rigorous evidence of the safety, efficacy, and reliability of AI algorithms before approving their use in community and hospital pharmacy settings. This process can be both time-consuming and resource-intensive.

Additionally, the collection, storage, and sharing of patient data require strict regulations to ensure patient privacy, slowing down the adoption of new AI technologies in pharmacy. Furthermore, many pharmacists may fear that AI technology will replace their jobs, so they exhibit resistance to change and reluctance to adopt AI due to concerns regarding job displacement, likely due to a lack of awareness regarding the potential benefits that AI can offer to their pharmacies[21]. In terms of AI technology costs, implementing AI systems in the pharmacy setting can be financially demanding, especially in developing countries such as Jordan[20]. Developing

and deploying AI systems necessitate the availability of hardware, software, and highly skilled personnel[22,23]. Although AI can aid in automating specific tasks, human involvement remains essential for verifying and making informed decisions. The requirement for human oversight introduces an additional level of complexity and resource allocation, as pharmacists may require additional training to efficiently utilize AI systems. In addition, covering the scarcity of AI expertise and resources inflates expenditures, further hindering access to these capabilities and constraining AI technology adoption. Absence of AI guidelines and laws in pharmacy practice is also an important barrier to AI technology adoption. Guidelines provide a framework for how AI should be developed, implemented, and used. Without clear guidelines, pharmacists might be uncertain about how to effectively integrate AI technology into their workplace. This uncertainty can lead to delays in the adoption of new technologies like AI.

Speaking of barriers to functioning AI technology in pharmacy settings, the lack of AI infrastructure that often exacerbates resource-limited environments can significantly limit the adoption of AI technology. This lack of necessary hardware, software, and technical expertise limits the potential benefits that AI can provide for pharmacy practice. Without a robust AI infrastructure, the full potential of AI technologies remains unrealized, hampering the ability of pharmacies to effectively utilize AI technology. Inadequate training and education are also barriers to AI operation, given the complexity of AI and the need to acquire pharmacists with sufficient knowledge and skills to deal with such a new technology. This knowledge empowers pharmacists to effectively utilize AI, and pave the way for a successful AI operation in pharmacy practice. Given the novelty of AI technology in the field of pharmacy, it remains vulnerable to technical issues and system failures that often mandate the involvement of skilled experts for resolution, leading to escalated expenses that impede its seamless operation. The limited connection between AI tools and pharmacy information systems coupled with the challenges AI tools face in managing complex medication-related tasks stands as major barriers to the successful functioning of AI in pharmacy. These issues obstruct the optimized utilization of AI's potential to elevate patient care, emphasizing a thorough evaluation and strategic approaches to overcome these challenges[10].

Adopting artificial intelligence (AI) within pharmacy practice has undeniable initial financial implications; however, the ongoing operational costs often emerge as the primary hurdle to broader implementation. These expenses stem from various necessities, such as acquiring specialized hardware, developing and integrating tailored software applications, adhering to meticulous data management protocols, and orchestrating consistent training programs, alongside the associated personnel costs. Yet, the strategic advantages of AI in pharmacy operations necessitate thorough consideration. Blue Yonder, a notable AI firm, fashioned advanced predictive software for the Otto Group, a leading German retailer. This algorithmic tool demonstrates an impressive 90% accuracy in predicting monthly sales[10]. Such precision has dramatically reduced delivery durations from weeks to merely one or two days, facilitating a direct-to-consumer model that bypasses intermediary warehouse storage. This instance underscores the potential cost efficiency of AI in inventory management and the potential long-term benefits of initial technological investments. In essence, while the integration of AI demands substantial financial and training investments upfront, its judicious deployment could yield operational efficiencies, time-saving measures, and considerable cost reductions.

Moreover, the absence of collaboration with other health professionals in terms of AI operations serves as a significant constraint on the way of AI operations in pharmacy. Without multidisciplinary collaboration, the full range of benefits of AI, such as accurate diagnosis and personalized treatment recommendations cannot be achieved. This limitation hinders the comprehensive implementation of AI in pharmacy operations and underscores the importance of fostering collaborative partnerships to maximize the benefits of AI.

The integration of AI in pharmacy ushers in a renewed focus on interprofessional collaboration. One salient benefit is its prowess in data sharing and consultation. Through AI's rapid analysis and presentation of patient data, pharmacists can efficiently relay crucial patient information to other healthcare professionals, thus enriching consultations and ensuring a comprehensive approach to patient care. Furthermore, AI-powered decision support systems are instrumental in highlighting cases requiring multidisciplinary intervention, seamlessly amalgamating expertise from various fields for judicious decision-making. AI also paves the way

Table 1. Barriers to adoption, functioning, and improvement of AI tools in pharmacy practice.

Barriers to Adoption	Barriers to Functioning	Barriers to Improvements
Lack of awareness and knowledge of AI applications in pharmacy	Insufficient AI infrastructure	Scarcity of AI-based research in pharmacy practice
Privacy concerns	Inadequate training and education	Limited access to updated AI algorithms and models
Regulatory restrictions	Technical issues and system failures	Challenges in data quality and standardization for AI applications
Fear of job displacement	Limited connection between AI tools and pharmacy information systems	Cost and resource constraints
Financial concerns	Difficulty in handling complex medication-related tasks	Limited feedback mechanisms for continuous AI improvement
Limited availability of AI expertise and resources	High operative costs	Ethical considerations and transparency in AI decision-making
Absence of AI guidelines in pharmacy practice	Absence of collaboration with other health professionals in terms of AI operations	Lack of collaboration and knowledge sharing among pharmacy professionals

for interprofessional training programs, designed to enlighten professionals across the spectrum about its intricacies, fostering mutual understanding and collaboration. Moreover, AI stands as a bastion for continuous feedback loops, guaranteeing that insights from its models are subjected to thorough cross-validation and refinement to maintain their accuracy and applicability.

It is essential to underscore that the advent of AI doesn't equate to diminished human participation. Instead, it reorients human efforts from routine undertakings to endeavors of higher value. For instance, with AI overseeing routine medication assessments, pharmacists can devote more time to intensive patient counseling, collaborative case evaluations, and strategic community health planning. The true essence of AI is crystallized in this nexus of enhanced collaboration and operational efficiency.

Improvement of AI technology in pharmacy practice encounters multiple obstacles, with a prominent barrier being the scarcity of studies that explore the effectiveness, applicability, and outcomes of AI implementation in pharmacy practice. This shortfall in research limits our understanding of the best pharmaceutical practices that AI can potentially enhance and the benefits AI could offer in terms of care protocols and patient outcomes. Another important barrier to enhancing AI within pharmacy practice is the difficulty of accessing up-to-date AI algorithms and models. This challenge can hinder the integration of the most effective and current AI solutions into pharmacy operations, leading to issues in patient care and operational efficiency. Apart from serving as a prominent obstacle to the adoption and operation of AI, the elevated cost associated with it also hinders the improvement of AI. This is due to the substantial resources required for comprehensive research, a process known for its resource-intensive nature. Without adequate funding and resources, the progress of AI technology enhancement cannot be achieved. Furthermore, the limited availability of feedback on AI performance in pharmacy presents a notable obstacle to its enhancement in this field, compounded by the absence of established guidelines in this context. Continuous feedback plays an essential role in identifying improvement areas, yet the deficiency in such feedback impedes the development and improvement of AI models, ultimately limiting their ability to deliver accurate and dependable insights for the enhancement of pharmacy interventions. As AI plays an important role in healthcare sectors such as pharmacy, ensuring ethical, fair, safe, and, error-free decision-making processes is paramount. Achieving a balance between developing AI capabilities and supporting ethical standards requires creating comprehensive frameworks that guide the development and enhancement of AI systems. Moreover, lack of collaboration and knowledge sharing among pharmacy professionals, which might not necessarily apply to all cases, could be attributed to the heavy workload and time constraints that pharmacists face, which leaves little room for teamwork, in addition to the competitive environments and concerns about patients' privacy, along with lack of incentives and resistance to change. Effective collaboration enables information exchange among pharmacy professionals, which is necessary for gaining valuable insights and experiences regarding AI. This, in turn, facilitates the development of AI tools that can be fully harnessed to improve pharmaceutical practices and patient outcomes.

The impact of AI adoption on human roles, skills, and costs is dynamic and dependent on context. Initially, implementing AI necessitates specialized skills and incurs significant costs; however, as tasks become automated, the need for human intervention decreases, potentially leading to long-term savings. Although ongoing maintenance costs are typically offset by these savings, the evolution of AI could lead to more user-friendly solutions, potentially reducing the need for specialized expertise and altering associated costs. In essence, while AI adoption involves upfront costs and expertise, it can mature to offer savings and operational efficiencies over time.

Strategies to overcome challenges to AI adoption in a pharmacy setting

With the application of effective strategies, we can get beyond these barriers and take advantage of AI implementation in pharmacy. In order to have comprehensive knowledge concerning AI and be able to use it effectively, AI education is essential to accomplish this through several ways such as attending seminars and conferences and participating in AI-related education and training programs[20]. To ensure the successful implementation of AI in the pharmacy setting, healthcare stakeholders, including government health departments, hospital administrations, and pharmacy professional associations, need to allocate significant financial support to address the costs associated with AI implementation. This includes ensuring the availability of AI-related software and hardware.

Adequate support should also be provided to hire skilled pharmacists capable of effectively utilizing AI and to provide them with ongoing training to stay updated with the latest advancements in AI technology. Privacy is a significant concern in the healthcare industry, primarily due to the presence of highly sensitive personally identifiable information in patient data. Consequently, the implementation of AI necessitates robust data protection measures to prevent unauthorized access and safeguard patient privacy. Pharmacies should employ privacy-enhancing technologies (PETs) such as data masking, differential privacy, homomorphic encryption, secure multi-party computation, and zero-knowledge proofs[24]. By utilizing these techniques, pharmacies can harness the benefits of AI while minimizing the risk of data breaches[25]. Overcoming the barrier of pharmacists' resistance to change can be achieved by addressing their concerns of AI, and demonstrating the tangible benefits and value-add of AI systems in pharmacy operations[20]. Collaboration between healthcare organizations, professional associations, regulators, and experts is essential in crafting comprehensive AI guidelines for pharmacy. These guidelines should cover the technical, ethical, legal, and operational aspects of AI, and serve as a blueprint for effective integration, operation, and

development of AI technology in the field of pharmacy. Governments and pertinent bodies should develop robust health policies centered on digital transformation. These policies should offer explicit directives for AI integration into healthcare, underscoring the significance of arming pharmacies with AI tools for superior patient care. Additionally, these policies might lay down frameworks for data protection, ensuring that personal data employed by AI models complies with stringent privacy standards. When considering the concerns pharmacists may have about potential job replacement, it becomes necessary to implement effective pharmacy staff training that includes acquiring pharmacists with new skills related to AI technology. In addition, enhancing collaboration between AI systems and human pharmacists in the decision-making process is essential. Furthermore, it is necessary to define job roles that facilitate the synergistic partnership between AI and human pharmacists. In such roles, AI can take over responsibility for routine tasks, allowing humans to focus on more complex, patient-centered duties. Moreover, it is advisable to conduct cost-effectiveness analyzes to evaluate whether the integration of AI into pharmacy operations has yielded significant benefits, enhanced pharmacy services, and enhanced patient privacy.

Following policy development, regulatory agencies become pivotal. These bodies must craft guidelines that streamline AI's integration into pharmacy care, ensuring ethical deployment of AI technology. They should also accelerate approval processes for AI-driven applications in pharmacies, thereby fostering innovation. Clear standards can guide pharmacies in adopting AI tools aligned with established norms, while regulatory agencies could also spearhead periodic reviews, adapting to the swiftly evolving AI landscape.

Education, too, remains indispensable. Universities ought to weave AI into pharmacy curricula, preparing the emerging generation of pharmacists to understand AI's role and ramifications in patient care. This integration should span theoretical knowledge, hands-on applications, and ethical considerations of AI in healthcare. Moreover, for current pharmacists, ongoing postgraduate training programs should be in place, ensuring they remain conversant with AI's latest evolutions; here, workshops, seminars, and online modules could prove instrumental.

For the seamless introduction of digital technologies into pharmacy practice, considerations should encompass infrastructure preparedness, professional adaptability, and patient receptivity. Evaluations must be conducted to gauge the present digital proficiency of pharmacies and discern gaps that warrant attention. By grasping the existing scenario and envisaging the desired outcome, a strategic pathway can materialize, bridging gaps and ushering in a digitally advanced future for pharmacies.

Effective integration of AI necessitates the acknowledgment and adaptation of established global best practices. Numerous jurisdictions have pioneered the incorporation of artificial intelligence in pharmacy, setting exemplary standards in the adoption, utilization, and enhancement of this advanced technology. Analyzing models from countries with sophisticated AI integration yields strategies for proficient implementation, addressing prevalent challenges such as data privacy, regulatory constraints, and resource allocation. However, the transference and adaptation of these practices must be meticulously tailored to align with the distinct regulatory frameworks, cultural nuances, and available resources of different jurisdictions. Each jurisdiction must undertake a comprehensive assessment of global practices in pharmacy and modify them to meet local needs and constraints, ensuring strategic implementation of AI solutions to optimize the benefits derived from AI. By fostering a global exchange of knowledge and experiences, we can leverage collective insights to improve the efficacy, safety, and accessibility of AI-driven solutions in pharmacies worldwide, ultimately enhancing patient care and health outcomes.

Conclusion

The integration of AI in the pharmacy practice presents both opportunities and challenges. AI systems hold the promise of streamlining tasks and enhancing operational efficiency, but certain challenges to AI adoption, operation, and improvement must be confronted. With the essential financial support and comprehensive education and training initiatives, these challenges can be surmounted. Moreover, it is crucial to highlight the advantages and added value offered by AI systems in pharmacy, alleviating concerns and exhibiting the potential for enhanced patient care and outcomes.

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