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PERSPECTIVES

AI-Driven Management of Type 2 Diabetes in China: Opportunities and Challenges

Zhifang He[1], Wenyu Li[2]

[1]Shanghai Xuhui Area Government of Community Office of Kangjian Xincun Street, Shanghai, People's Republic of China; [2]School of Marxism, Capital Normal University, Beijing, People's Republic of China

Correspondence: Wenyu Li, Email 13241466866@163.com

Abstract: With the aging of China's population and lifestyle changes, the number of patients with type 2 diabetes (T2D) has surged, posing a significant challenge to the public health system. This study explores the application and effectiveness of artificial intelligence (AI) technology in T2D management from a Chinese perspective. AI demonstrates substantial potential in personalized treatment planning, real-time monitoring and early warning, telemedicine, and health management. It not only enhances the precision and convenience of treatment but also aids in preventing and managing complications. Despite challenges in data privacy, technology popularization, standardization, and regulation, AI technology's continuous maturation and expanded application suggest its increasingly pivotal role in T2D management. In the future, through interdepartmental collaboration, policy support, and cultural adaptation, AI is poised to bring revolutionary changes to diabetes management in China and globally.

Keywords: artificial intelligence, type 2 diabetes, diabetes management, personalized treatment, telemedicine, data privacy and security

Introduction

Given that China has the largest aging population globally, it stands out prominently among countries experiencing rapid aging.[1] Accompanying this aging trend, the prevalence of type 2 diabetes (T2D) is also rising,[2] making T2D one of the major public health challenges faced by China.[3] According to estimates, the number of diabetic patients in China has reached 114 million,[4] accounting for one-third of global diabetic patients. Therefore, adopting effective treatment and intervention measures to improve the health status of Chinese diabetic patients has become an urgent and severe issue.

Artificial intelligence (AI), as a rapidly developing technological field, is gradually demonstrating its substantial potential in transforming chronic disease management, particularly in diagnosing and treating T2D.[5] Globally, AI applications in diabetes management are advancing rapidly, with significant progress in personalized treatment planning, real-time monitoring, and telemedicine. Countries such as the United States and Europe have seen widespread adoption of AI-driven technologies, such as continuous glucose monitoring systems integrated with AI algorithms, to improve diabetes outcomes.[6] However, China's aging population and large rural demographics present unique challenges that necessitate tailored solutions. The integration of AI technology in China's diabetes management strategies is therefore particularly important, as it offers the potential to alleviate the pressure on the healthcare system and improve patient outcomes through real-time, remote monitoring and personalized care.[7] Through precise data analysis and pattern recognition capabilities, AI applications are expected to significantly reduce the escalating healthcare costs associated with diabetes.[8] In addressing the unique challenges posed by China's aging society, the integration of AI technology is particularly important and timely, as it can effectively alleviate the pressure on diabetes healthcare, covering multiple key aspects from prevention,[9] early diagnosis[10] to treatment, ongoing care,[11] and long-term follow-up. For this perspective study, we conducted a comprehensive literature review of existing research on AI-driven diabetes management in China. We analyzed data from published studies, reports, and policy documents to identify trends, challenges, and opportunities

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in the field. This multi-method approach allowed us to synthesize a comprehensive perspective on the role of AI in managing type 2 diabetes in China.

Application of AI in T2D Management

In the comprehensive management of T2D, AI is gradually showing its irreplaceable value, potentially covering multiple key areas such as diabetes prediction, continuous glucose monitoring, insulin injection guidance, and daily diabetes care.[12] This paper aims to delve into the specific applications of AI in T2D management and refine its roles into three core categories: precise formulation of personalized treatment plans for diabetes, establishment of real-time condition monitoring and early warning systems, and optimization of telemedicine and health management.

This paper addresses the following three questions:

1. What irreplaceable value does AI demonstrate in managing type 2 diabetes, and which key areas does its potential cover?
2. What are the three core categories of AI's role in T2D management?
3. For AI's three major management processes in T2D management—personalized treatment planning, real-time monitoring and early warning, and telemedicine and health management—elaborate on AI's specific applications and the benefits they bring in these processes.

Personalized Treatment Planning

AI can tailor personalized patient treatment plans by analyzing multidimensional data such as medical records, lifestyle habits, and genetic information. This includes dietary advice, exercise plans, drug selection, and dosage adjustments to maximize blood glucose control and reduce complications. With AI's assistance, patients can precisely control their diet and formulate relevant plans. A research[13] proposed a digital integrated healthcare platform using AI for dietary management, combined with a real-time continuous glucose monitoring system (CGMS), to improve self-management for patients with T2D. A research[14] suggested that AI can guide people's lifestyles, providing personalized dietary and exercise advice through machine learning algorithms combined with electronic medical record data. Research findings[15] revealed that an integrated digital healthcare platform with AI-driven dietary management can improve blood glucose levels and reduce weight in adults with T2D.

Furthermore, AI can adjust the dosing accuracy in real-time in drug selection and dosing. A research[12] indicated that AI assists insulin usage in diabetes care, such as smart insulin pens and artificial pancreases. Smart insulin pens, connected to mobile devices via Bluetooth, enhance dose accuracy and improve patient compliance.

Recent studies[16,17] have shown that automated insulin delivery (AID) plays an increasingly important role in diabetes management. Hybrid closed-loop systems have become part of routine clinical practice for type 1 diabetic patients.[18] Recent research on T2D has also found[19] that the feasibility trial results of AID in adults with T2D with suboptimal glycemic outcomes demonstrate the potential of this technology in T2D applications.

For diabetes complications, AI can enable targeted treatment. A research[20] described that AI technology, particularly deep learning (DL), has been used to develop automated detection algorithms for diabetic retinopathy, indicating AI's significant potential in identifying and managing diabetes complications.

Real-Time Monitoring and Early Warning

In the modern healthcare sector, integrating AI with wearable devices and smart home systems has revolutionized the monitoring of physiological parameters for diabetes patients. AI technology enables real-time monitoring of crucial indicators such as blood glucose levels, heart rate, and blood pressure. The system immediately triggers alerts upon detecting abnormalities, prompting patients and healthcare providers to take appropriate actions. This real-time monitoring approach has significantly enhanced the efficiency and precision of diabetes management. A research[21] demonstrates that AI technology exhibits substantial potential in blood glucose prediction, providing warnings of hyperglycemic or hypoglycemic events, thereby enabling patients to take preventive measures promptly. The study encompasses various

machine learning models, including Random Forest, Support Vector Regression, and deep learning techniques, particularly Long Short-Term Memory (LSTM) networks.

Furthermore, Continuous Glucose Monitoring (CGM) technology has been proven to significantly reduce the risk of hyperglycemia in non-insulin-treated patients.[22] CGM systems integrated with AI technology improve detection results' accuracy and facilitate more convenient glycemic control. A research[23] have developed an AI-assisted CGM digital system that effectively reduces blood glucose fluctuations by analyzing patients' daily diet, activity levels, and food consumption records. With breakthroughs in wearable sensor technology and advanced biomedical signal processing, non-invasive glucose monitoring has become a reality. These technologies estimate blood glucose concentrations through various methods such as optics, biochemistry, microwaves, saliva, and tears, offering patients a more comfortable monitoring option than traditional invasive methods. Currently, multiple non-invasive monitoring devices are available in the market, and AI technology demonstrates significant potential in enhancing these devices' accuracy, cost-effectiveness, portability, and efficiency.[24]

Telemedicine and Health Management

AI-driven telemedicine platforms are gradually transforming traditional healthcare service models. Patients can access professional medical consultations and services without frequent hospital visits. Through this platform, patients can upload medical imaging data, which AI algorithms analyze to provide precise diagnostic and treatment recommendations, thereby significantly expanding the coverage and efficiency of healthcare services.[25] Doctors can use modern tools such as video calls and online consultations to stay updated on patients' condition changes, adjust treatment plans in real-time, and provide necessary health education and psychological support. Additionally, AI technology can automatically optimize follow-up plans based on patient feedback and treatment responses, ensuring the continuity and effectiveness of disease management. A research[26] indicates that remote monitoring is more effective than traditional care methods in controlling blood glucose levels for diabetes patients.

Furthermore, diabetes communities on social media, such as the #t1d and #t2d hashtags on Twitter, create a space for patients to share personal experiences, daily challenges, and anxieties. These online communities provide valuable emotional support for patients and offer rich data resources for medical researchers, aiding in identifying and optimizing key elements in diabetes management.[27] Moreover, researchers have developed an integrated image-language system (DeepDR-LLM)[28] using large language models and image-based deep learning techniques, providing personalized diabetes management suggestions for primary healthcare workers. In retrospective and prospective studies, this system has been proven to significantly improve adherence to diabetes management, referral adherence for complications, and the quality of management recommendations.

AI plays an increasingly crucial role in the management of T2D. By providing personalized treatment plans, real-time health monitoring, and convenient telemedicine services, AI technology has significantly improved the effectiveness of diabetes treatment and patients' quality of life. Applying these innovative technologies not only enhances the precision and convenience of treatment but also aids in preventing and managing diabetes complications, providing patients with comprehensive health management support. With continuous technological advancements and deeper applications, the future management of diabetes is expected to achieve more intelligent and personalized healthcare services.

Effectiveness of AI-Driven Management

Currently, AI can analyze vast amounts of data generated by medical devices, particularly in disease diagnosis, emergency care, and personalized medicine.[29] The application of AI technology in diabetes management offers numerous advantages, such as early prevention and intervention in diabetes,[30] improving the accessibility and efficiency of healthcare services,[25] and positively impacting patients' self-management abilities and treatment adherence.[26]

Improving Management Efficiency

The application of AI technology in diabetes management has significantly enhanced efficiency in this field. By automatically analyzing massive medical data, AI can quickly identify diabetes risk factors, assess disease severity, and formulate personalized intervention strategies, effectively reducing the burden on healthcare workers. Moreover,

Continuous and Flash Glucose Monitoring (CGM and FGM) devices provide patients with more effective disease management tools. For instance, by offering up to 14 days of blood glucose data cycles, these devices help better assess glucose fluctuations, improving short-term glycemic control.[27] Advances in AI technology have also driven the development of continuous glucose monitoring devices that can measure blood glucose levels without traditional invasive needle sticks. For example, the Eversense CGM system can provide real-time glucose monitoring data for up to 90 days,[12] greatly enhancing the convenience and comfort of glucose monitoring for patients. Through telemedicine platforms, patients can upload medical imaging data, which AI algorithms analyze to provide precise diagnostic and treatment recommendations, not only improving the accessibility of healthcare services but also enhancing service efficiency.[25] A research[31] shows that using machine learning algorithms, especially Random Forest algorithms, can construct decision trees to predict drug prescriptions for T2D, thereby improving the efficiency of diabetes medication management.

Furthermore, a research[32] indicate that Recurrent Neural Networks (RNNs) are effective methods for detecting and analyzing physical activity in diabetes patients. This approach, through a deep understanding of individual activity patterns, contributes to more personalized and effective diabetes management strategies. In summary, the application of AI technology in diabetes management not only improves the precision and convenience of treatment but also aids in preventing and managing complications, providing diabetes patients with comprehensive health management support. With continuous technological development, the future management of diabetes is expected to achieve more intelligent and personalized healthcare services, further enhancing patients' quality of life and treatment outcomes.

Enhancing Treatment Outcomes

The precise implementation of personalized medical plans has become a key factor in improving treatment outcomes. Through deep analysis of patients' clinical data and lifestyle habits, AI technology can tailor treatment plans for each patient, ensuring precise adjustments to medication doses and types, effectively controlling blood glucose levels, and reducing the risk of complications. A research[23] propose an AI-based dietary advisor called "FoodLens". This technology can identify food types by analyzing a single photo uploaded by the user and providing detailed nutritional information. This innovative intervention allows patients to quickly adjust their dietary structure based on real-time glucose monitoring values, maintaining a healthy lifestyle. Another research[13] explored the application of a digital integrated healthcare platform combined with AI-driven dietary solutions and real-time CGM systems in T2D. By providing personalized dietary suggestions and real-time glucose feedback, this comprehensive intervention may positively impact patients' self-management abilities, thereby improving overall health status. Additionally, a research[33] emphasizes the importance of Education, Case Management, and Advanced Practice Pharmacy Services (ECP) in diabetes management. This multi-dimensional service model can significantly improve diabetes-related indicators in patients, thereby enhancing treatment outcomes.

Enhancing Patient Adherence

AI-driven telemedicine and health management platforms provide diabetes patients with more convenient and personalized service experiences, significantly enhancing patient engagement and treatment adherence. Patients can now grasp their health status and treatment progress in real-time, more effectively collaborating with healthcare teams in diagnostic and treatment activities. The Utah Remote Monitoring Project[34] demonstrates that remote treatment technology positively impacts patients' self-management abilities and treatment adherence. Furthermore, implementing telemedicine services strengthens the connection between patients and healthcare providers, particularly for patients using CGM, who can view real-time glucose changes along with their healthcare providers and discuss and adjust treatment plans accordingly.[35] The application of AI technology in the field of diabetes management not only improves the efficiency and treatment outcomes of disease management but also enhances patient adherence.

Challenges

With its vast territory, China exhibits significant disparities in the level of medical informatization across the country. Five provinces and municipalities, including Shanghai, Henan, Hunan, Chongqing, and Xinjiang, have established provincial

electronic medical record databases, while 27 provinces (93.1%) have yet to do so.[36] A complete framework for regional medical big data is still lacking. In managing diabetes, the application and popularization of AI technology face severe challenges.

Data Privacy and Security

Diabetes management involves a large amount of sensitive personal information and medical data. A certain level of data sharing is required to convert this data into treatment outcomes. However, encouraging data sharing necessitates numerous cultural and policy shifts. Even in the United States, the "Liberating Data for Public Value" concept for public data has not been fully accepted and recognized. Without a culture of information sharing, the collection and transmission of data will be restricted, reducing the effectiveness of big data applications. If data sharing is implemented, ensuring the security and privacy of this data during collection, storage, and processing becomes a crucial issue. We need to establish standards for data sharing to improve data quality and the accuracy of analysis and prediction.[37]

Additionally, robust data protection mechanisms must be established to prevent data leaks and misuse. A project[38] struck a balance between usability and privacy by allocating corresponding data and scheduling computational resources for analysis and application based on the security and permissions of different users. The aggregation and effective application of big data can be achieved through new technologies, new underlying storage infrastructures, and new holistic solutions.

Technology Popularization and Acceptance

Despite the significant advantages of AI technology in diabetes management, its popularization is still constrained by various factors, including technical costs, acceptance by healthcare professionals and patients, and infrastructure development. Greater promotional efforts are needed to enhance society's understanding and trust in AI technology. The construction of medical big data is a lengthy and complex process, highly dependent on collaboration from all parties and coordination at higher levels. The administrative divisions of China's medical institutions are complex and diverse. For example, a university's affiliated hospital may be simultaneously under the jurisdiction of both the school and health administrative departments, which can lead to institutional deficiencies. The starting point of China's medical and health informatization construction is low, and it has long been characterized by repeated and disorderly development at a low level, resulting in issues with information integration across systems and data sources within hospitals.[39]

Standardization and Normalization

The application of AI in diabetes management is still in the exploratory stage, lacking unified standards and norms. Relevant standards and guidelines need to be formulated to regulate AI technology's research and development, application, and evaluation processes, ensuring its safety and effectiveness. For instance, the Xiangya Medical Big Data Storage Platform in China[38] achieves real-time synchronization based on distributed technology. It has developed a unified data interface based on databases and data platforms, allowing the data acquisition system to provide data entry based on this interface and supporting multiple input terminals. It can also be accessed via VPN from the Internet, ensuring security from external environments.

In summary, the development of AI technology for diabetes management in China faces multifaceted challenges, including uneven medical informatization, data privacy and security issues, low technology popularization, and a lack of standardization. Cross-departmental cooperation, policy support, and cultural changes are needed to promote its development and application.

Future Prospects

With the continuous advancement of AI technology, we anticipate it will play a more crucial role in disease prevention, early diagnosis, personalized treatment, and patient follow-up. Through deep learning and big data analysis, AI can more accurately predict disease risks, particularly providing early interventions for high-risk populations, thereby reducing the incidence of T2D. The "Healthy China Initiative - Diabetes Prevention and Control Action Implementation Plan (2024–2030)", released in July 2024, explicitly states that by 2030, the treatment rate, control rate, and screening rate for complications of diabetes should continue to improve, while the early mortality rate should continue to decline. The disease burden should be effectively controlled. As an important direction for AI application, personalized medicine will provide more precise treatment plans for T2D. The popularization of remote medical care and health management will enable diabetes patients to access more

convenient medical services. AI-driven remote monitoring systems can track patients' physiological indicators and blood glucose levels in real-time, adjusting treatment plans promptly and reducing the number of hospitalizations and emergency visits. However, to achieve these goals, we must overcome the current challenges. This includes improving medical informatization, establishing a nationwide electronic medical record database, and achieving standardization and interconnectivity of medical data. Simultaneously, we must strengthen data privacy and security protection, formulate strict data sharing and usage norms, and ensure the safety of patient information.

Furthermore, we need to increase the acceptance of AI technology by healthcare professionals and patients through education, training, and promotional activities, enhancing confidence and support for AI technology across society. Finally, the government and relevant departments should increase investment in the research, development, and application of AI technology, encourage innovative collaboration between research institutions and enterprises, and promote the application of AI technology in diabetes management. Through policy guidance and financial support, we should facilitate the deep integration of AI technology with the medical and health field, providing a solid foundation for building a more efficient and precise diabetes management system.

In Asia, particularly in China, the rapid increase in the prevalence of type 2 diabetes has necessitated innovative approaches to management. AI technology, with its ability to process vast amounts of data and provide personalized insights, offers a promising solution. However, the adoption of AI in diabetes management in China is still in its early stages, and more research is needed to explore its full potential and address the unique challenges faced by the region. In conclusion, the application of AI technology in the management of T2D in China holds great promise. However, multidisciplinary collaboration, policy support, technological innovation, and cultural adaptation are required to realize its potential. Through these measures, we believe AI technology will bring revolutionary changes to diabetes management in China and globally, providing patients with higher-quality and more efficient medical services.

Data Sharing Statement

The original contributions presented in the study are included in the article. Further inquiries can be directed to the corresponding authors.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agreed to be accountable for all aspects of the work.

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