Practice and Optimization of a Cross-scene AI Intervention Model for HIV Patients' Multi-dimensional Self-management

Yuan Fu

Department of Infectious Diseases, Chongqing Hechuan People's Hospital, Chongqing, China

992659305@qq.com

Keywords: Cross-scene artificial intelligence intervention mode; HIV patients; Multidimensional self-management

Abstract: In the context of HIV/AIDS prevention and control, patient self-management is of paramount importance. The advancement of artificial intelligence (AI) has introduced a new opportunity to enhance the multidimensional self-management capabilities of individuals living with HIV through cross-scenario AI intervention models. This paper seeks to investigate the application and optimization of such models in the multidimensional self-management of HIV patients. First, this paper gives a theoretical foundation based on health behavior theory and human-computer interaction. Second, it develops a comprehensive self-management framework for HIV patients that encompasses multiple dimensions. This paper elaborates on the implementation of cross-scenario AI interventions, including mHealth and AI chatbot interventions, as well as family-centered AI support systems. Furthermore, it highlights some significant problems encountered in practical applications, such as the algorithm's insufficient reliability and the risk of sensitive patient data being leaked. At the same time, it also proposes corresponding improvement methods to address these issues. These methods include utilizing multimodal data fusion, implementing more robust privacy protection measures, engaging users in the development process, and effectively integrating these AI tools into doctors' daily workflows. Finally, this paper concludes that optimizing these AI intervention models that can be used in different scenarios can greatly help HIV-infected people improve their self-management ability, which can provide important support for our whole society's efforts to fight AIDS.

1. Introduction

1.1 Research Background

With the popularization and advancement of Highly Active Antiretroviral Therapy (HAART), AIDS has evolved from a fatal disease into a manageable chronic infectious disease, and the life expectancy of people living with HIV has been significantly prolonged. In this context, the focus has expanded from treatment to enhancing the long-term quality of life and self-management capabilities of patients.

The health management of people living with HIV also faces numerous new challenges, including the complex needs of long-term medication adherence, psychosocial adaptation, and symptom management. Traditional medical models often struggle to comprehensively address these multidimensional needs, particularly for patients in remote areas and special populations, who face significant challenges in accessing and maintaining continuity of medical resources [1]. In recent years, the rapid development of AI has provided new avenues for the self-management of HIV patients. The application of AI in the medical field has transitioned from theoretical research to practical implementation, demonstrating great potential in areas such as disease prediction, auxiliary diagnosis, and health management. In the field of HIV prevention and control, AI tools are utilized in various aspects, including risk prediction, clinical decision support, and personalized interventions, creating new opportunities to build a cross-scenario, personalized self-management model for HIV patients.

  DOI: 10.25236/iwmecs.2025.031

1.2 Research Significance

This study focuses on the application of cross-scenario AI intervention methods in the self-management of HIV patients, possessing significant theoretical value and practical significance. In the theoretical dimension, it expands the theoretical system of chronic disease management and the depth of integrated application of AI in the medical and health fields, providing a reference for constructing a more comprehensive theoretical system for the whole-course management of HIV. In the practical dimension, studying AI-led self-management pathways for HIV patients holds practical value for improving patient health status, optimizing the allocation of medical resources, and reducing medical expenditures. Particularly crucial is the fact that cross-scenario AI intervention breaks through the spatio-temporal barriers of traditional medical services, achieving smooth transitions across multiple scenarios such as hospitals, homes, and communities, and providing continuous support for patients. This model is especially suitable for the management of chronic infectious diseases like HIV, as it can not only meet patients' requirements but also provide individualized and timely guidance.

2. Theoretical Foundation

2.1 Health Behavior Theory

Health behavior theory offers a theoretical foundation for modifying the behaviors of individuals with HIV. The theory posits that health-related behavior is shaped by a confluence of factors, encompassing both individual perceptions and the broader social environment. Through this framework, it is possible to dissect the motivations and determinants of a patient's health-related behaviors, which in turn facilitates the development of precise intervention strategies. These strategies aim to enhance the patient's awareness of their health-related behaviors, mobilize social support systems to encourage family and friends to offer support and oversight, and guide the patient in developing a healthy lifestyle and improving self-efficacy. Central to this theory is the principle that behavior modification is an incremental process, necessitating gradual guidance to foster sustainable, healthy habits and greater self-management capabilities [2].

2.2 Human-Computer Interaction Theory

Human-computer interaction theory focuses on exploring the mechanisms and pathways of interaction between individuals and computer systems. In the context of AI intervention in diverse scenarios, human-computer interaction theory informs the development of more efficient interactive interfaces and methods. Through the refinement of interactive design, patients can more conveniently engage in dialogue and collaboration with AI systems. By utilizing natural language interaction, patients can converse with the system by imitating interpersonal communication patterns. The system adjusts its functions and services based on patient feedback information. Human-computer interaction theory emphasizes optimizing user experience, reducing patients' psychological rejection of technology, and increasing their willingness to participate and exercise autonomy in using AI intervention systems.

3. A Framework for Self-management of HIV Patients

Self-management of HIV-infected people is a complex concept, involving many aspects. Mastering its multidimensional structure is the foundation for developing an effective AI intervention strategy. According to existing assessment tools for the self-management of HIV-infected individuals/AIDS patients, most include five major dimensions and thirty specific items, covering areas such as daily life regulation, mastery of disease knowledge, response to physical signs, control of medication adherence, and psychological and mental adjustment [3]. The various dimensions are interconnected, shaping the overall framework of self-management for HIV-infected individuals.

3.1 Daily Life Management and Maintenance of Health-related Behavior

The proper arrangement of daily life constitutes a key component of self-management for HIV patients, specifically covering healthy living patterns such as maintaining a regular daily routine, a scientific diet, moderate physical activity, and avoiding high-risk behaviors. It focuses on guiding patients to integrate disease management strategies into daily practice and to cultivate and consolidate healthy daily behavioral norms [4]. For HIV-infected individuals, effective regulation of daily life can support the normal functioning of the immune system, reduce the likelihood of complications, and thereby enhance overall health status. With the help of AI technology's intelligent reminders, exercise monitoring, and personalized guidance, patients can be assisted in shaping and adhering to health-related behaviors, fostering a positive health cycle.

3.2 Treatment Compliance Management

For HIV patients, self-management is centered on the management of treatment adherence, the effectiveness of which directly influences the outcome of antiviral therapy. This process encompasses multiple practices, including taking medication on time, completing examinations as per medical advice, and attending follow-up appointments regularly. Maintaining excellent medication adherence (generally exceeding 95%) is of critical importance for preventing the development of viral resistance. Intelligent intervention methods, such as smart reminder systems and personalized feedback, can effectively enhance patients' adherence to medication. AI-driven chat assistants can understand patients' medication barriers, provide personalized suggestions, and timely remind patients about medication and follow-up appointments through daily communication. Table 1 illustrates the key dimensions and content of self-management for HIV patients.

Table 1 The key dimensions and contents of self-management for HIV patients

Dimensions	Contents	The impact on health outcomes
Treatment compliance management	Medication on time, regular review, and follow the doctor's advice.	Prevent drug resistance, maintain viral suppression, and prolong survival.
Symptom analysis	Identify and manage symptoms, side effects, and seek help.	Improve the quality of life, reduce complications.
Emotional cognitive management	Emotion regulation, stress response, and positive attitude training	Improve mental health and enhance confidence.
Daily life management	Avoid dangerous behavior, maintain a healthy diet, and engage in moderate exercise.	Maintain immune function and improve overall health.
Disease knowledge learning	Mastery of knowledge about diseases, treatments, and self-care skills.	Improve doctor-patient communication and enhance patients' self-management abilities.

3.3 Treatment of Symptoms and Side Effects

Symptom management pertains to patients' cognition, observation, and handling of HIV-related discomforts and adverse drug reactions. It constitutes the most information-rich module within self-management assessment tools, and successful regulation can help patients better tolerate the discomfort during treatment, thereby reducing the likelihood of therapy discontinuation. An intelligent system utilizes natural language processing technology to comprehend the symptoms reported by patients. It provides personalized guidance and, in some cases, encourages patients to seek professional medical help. Timely assistance is essential for improving patients' quality of life and ensuring the continuity of their treatment [5].

3.4 Emotional Cognitive Management and Mental Health

Emotional cognitive management mainly focuses on patients' psychological adjustment and

emotional control ability, including coping with the sense of shame brought by HIV diagnosis, reducing stress and maintaining a positive attitude. People living with HIV often face psychological problems such as depression and anxiety, which may significantly impact treatment adherence and overall health levels [6]. Intelligent conversational agents and virtual healthcare assistants, utilizing cognitive behavioral therapy, and emotional monitoring capabilities, offer patients immediate psychological support. This assistance is particularly crucial in situations where access to professional psychological resources is limited.

4. Application of Cross-scene AI Intervention Mode

The application of AI in HIV patient management is gradually shifting from theoretical exploration to practical application, leading to the development of interdisciplinary intervention methods. These methods leverage the unique advantages of AI technology to develop a continuous and comprehensive support system for patients by customizing services, continually updating knowledge [7], and integrating multidimensional information. In this section, we will discuss the practical applications and effects of AI interventions in various scenarios.

4.1 Mobile Health (mHealth) and AI chat robot intervention

The integration of mHealth and AI chatbots has become an effective means of increasing HIV testing rates and improving treatment adherence. A randomized controlled trial conducted by Yale University in Malaysia has confirmed that AI chatbots possess significant potential in promoting HIV testing. This study uses AI chatbots to provide users with personalized information support, covering topics such as Pre-Exposure Prophylaxis (PrEP), mental health, and HIV testing. Moreover, they will flexibly adjust the chat process based on user feedback.

mHealth interventions, driven by AI, possess excellent scalability and privacy security, making them particularly suitable for providing services to specific populations. Chatbots can integrate many practical functions, such as helping us assess risks, guiding us to testing sites, and explaining test results. They form a complete testing support system. Compared to the previous method of sending health notices to a large group of people, AI chatbots can interact with us individually and provide guidance tailored to our specific needs, as well as our individual ideas and habits [8].

4.2 Family-Centered AI Support System

The family environment has a central influence on the self-care process of HIV patients, particularly among the adolescent and elderly groups. The use of family-based smart assistance systems, which leverage intelligent terminals, voice interaction, and remote tracking, transforms the home environment into a setting for long-term health maintenance. An exploratory study on the "Family Bond" conducted in Zambia has confirmed that family-based intervention programs can enhance the effectiveness of antiretroviral therapy for adolescent HIV patients while also alleviating their sense of stigma associated with the disease.

Home-centered AI intervention plans generally encompass many elements, including an intelligent medicine box, environmental sensing devices, and voice communication ports. The intelligent medicine box is used to track whether we take medicine regularly. Environmental sensing equipment can analyze patients' daily activity habits. The voice communication port can provide question-and-answer functions. Home-based information exchange channels promote the joint participation of patients and family members in management control. High technology fosters a caring home atmosphere, which is beneficial in enhancing the positive impact of family bonds on disease management.

4.3 Clinical Decision Support and Personalized Care Planning

In the medical and healthcare field, an AI platform will process a large amount of patient information, provide strategic direction for clinical staff, and help formulate personalized diagnosis and treatment plans. AI-driven Clinical Decision Support Systems (CDSS) will combine multiple data sources, including electronic health records and laboratory findings, enabling medical

professionals to make informed interventions quickly [9]. This technology utilizes machine learning algorithms to analyze historical data, predict the effects of various treatment schemes, and assist doctors in identifying the most effective drug combination. Intelligent solutions can also create personalized educational content for patients and adjust materials according to their treatment progress and unique conditions, thereby improving their ability to effectively manage their own health.

4.4 Community Support

Community support is crucial in our fight against HIV, and the integration of AI technology can enhance it, enabling us to help more people. Through the matching mechanism of AI, virtual communities can connect patients with similar situations, allowing everyone to share experiences and learn from one another more effectively. By utilizing natural language processing technology, it can thoroughly analyze community discussions, identify emergencies that require professional intervention and initiate the alert program promptly.

With the development of rural areas, we found that case management strategies are particularly useful under conditions of limited resources in exploring health management for AIDS patients in Chongqing's mountainous areas. AI can enhance case management by automatically completing daily follow-ups, screening high-risk groups, and planning routes for community workers. This AI-assisted community support mechanism is particularly suitable for rural areas, which can enhance service levels and operational efficiency.

5. The Challenges and Optimization Strategies of Cross-scenario AI Intervention

In the intervention process for social support and stigma among the elderly HIV/AIDS population, although the use of AI has broad prospects, it encounters multiple complex challenges in practical applications across different scenarios (family, community, and medical institutions). Identifying these challenges and formulating systematic improvement strategies are essential for leveraging technology's empowering potential.

5.1 Key Challenges in Implementation

5.1.1 Insufficient Algorithm Reliability and Data Interoperability Barriers

The application of AI in the field of elderly HIV care is still in its preliminary stage, with the main difficulties focusing on algorithmic performance and data acquisition capabilities. The lack of specific stability in algorithms is manifested in the form of delayed risk warnings or disjointed communication content due to the absence of corpora and training data tailored to the special physiological and psychological characteristics of older people. Patients' social support information, psychological assessment results, and clinical diagnosis and treatment records are stored separately on independent platforms, such as community health centers, CDCs, and hospitals. The standards of each system vary and are isolated from one another, causing a "data silo" phenomenon[10].

5.1.2 Risk of Sensitive Data Leakage and Lack of Algorithm Fairness

In the realm of AIDS research, the confidentiality of critical data and the fairness of algorithms are regarded as inviolable principles. Chief among the concerns is the potential disclosure of sensitive information; a patient's HIV status, psychological well-being, and social connections are all considered highly confidential. A breach at any stage of an AI system's data lifecycle—whether collection, transmission, storage, or analysis—would deal a devastating second blow to patients. Moreover, the inherent risk of algorithmic unfairness is a significant concern, as it can give rise to "technical bias."

5.1.3 Digital Divide

For these elderly AIDS patients, it is really difficult to convince them of AI. Firstly, these people have been suffering from social prejudice, so they are very careful about any high-tech that may expose their health, and don't dare to believe it. Secondly, the intrinsic "black box" characteristic of AI renders its decision-making processes hard to understand, thereby hindering the establishment of

trust. The digital divide significantly affects many seniors' ability to use smart devices. These challenges are compounded by age-related declines in sensory functions, such as vision and hearing, as well as economic limitations that prevent them from affording the costs of necessary devices.

5.2 Multi-dimensional Optimization Path

5.2.1 Design of Multimodal Data Fusion and Personalized Interaction

To enhance the precision and universality of AI intervention, in-depth improvements are conducted across the dimensions of data and interaction, with multimodal information integration at the core. It is imperative to ensure the secure communication of information such as voice and text across medical documents and wearable device data, all while strictly safeguarding privacy. It is necessary to create a real-time updated individual digital replica to provide AI with decision support, thereby achieving customized interaction planning. AI interaction platforms must be designed with age-friendly features; the interaction content should be flexibly adjusted based on the patient's cognitive level and emotional state. For groups with a high degree of shame, priority should be given to providing anonymous peer support channels. At the same time, accurate science communication content should be delivered to those lacking information, thereby achieving precise assistance tailored to each individual.

5.2.2 The Application of Privacy Protection Technology and the Construction of Ethical Framework

Through the dual support of cutting-edge technology and rigorous ethics, we jointly address challenges in technological safety and fairness. In the technical domain, we should prioritize the adoption of privacy-preserving computing solutions to minimize the risks of data leakage. From a management perspective, it is essential to establish robust ethical norms and establish an ethical assessment committee comprising medical experts, scholars, community representatives, and patients to conduct continuous reviews and adjustments of AI algorithms, ensuring a transparent decision-making process. Additionally, establish clear systems for human intervention and accountability to ensure that technological applications strictly serve an "auxiliary" role rather than "replacing" humans.

5.2.3 Promote the Cultivation of Trust System

To bridge the trust barrier and the digital divide, the key is to guide the target group to deeply participate in and control the design process. This mode of joint research and development emphasizes that a joint design team should be set up from the beginning of the project, which should include elderly patients with AIDS, their families, doctors, nurses, and community service personnel. Through methods such as seminars and model validation, it is ensured that the artificial device truly aligns with their practical needs and operational skills. Furthermore, it is recommended to use concise language to explain the AI's capabilities and limitations for users, and to grant users absolute control over data collection and usage, ensuring that users can always access support when needed.

5.2.4 The Establishment of Medical Process Integration and Long-term Support Mechanism

To ensure the successful implementation and sustainable operation of AI interventions, it is necessary to conduct system integration and innovation of mechanisms. The seamless integration of medical workflows means that AI tools should be embedded as plug-ins or modules into existing workflows, such as Electronic Health Record (EHR) systems and community follow-up management platforms, automatically generating early warning prompts or auxiliary decision-making suggestions for medical staff, without adding to their operational burden. More importantly, it is necessary to establish a long-term support mechanism, which involves promoting the inclusion of mature AI intervention services in the public health service procurement catalog or the scope of medical insurance payment by government health departments, thereby forming stable financial support. Moreover, it is recommended to establish an interdisciplinary operations team responsible for the continuous iteration, maintenance, and user support, thereby ensuring that the innovative model maintains its public service capability.

6. Conclusion

This research examines the practical application and improvement strategies of multi-scenario AI intervention models in the multidimensional self-management of individuals with HIV. By integrating mHealth, family care, clinical guidance, and community services, it meets patient needs in daily activities and symptom management, significantly enhancing the integrity and continuity of the self-management system. Research indicates that resources such as intelligent dialogue assistants and customized decision support tools are highly beneficial in enhancing patient participation.

However, this model encountered some challenges in practical use, such as unstable algorithms, data confidentiality, user trust, and how to integrate into the medical system. Therefore, our research proposes several improvement methods, including the use of multimodal data integration to enhance the accuracy of interventions, while ensuring the confidentiality and integrity of data in accordance with ethical standards. We also achieved deep integration with the medical system through process reengineering.

Cross-scene AI intervention should continue to improve technical stability and pay attention to humanistic care, which can promote the integration and innovation of medical and engineering fields and finally create a patient-centered intelligent health management system. It sets a new example for long-term care of HIV patients, provides a framework for digital management of chronic diseases, and is of great significance for making public health services more intelligent.

References

[1] Koenig L J, Lyles C M, Higa D, et al. Research synthesis, HIV prevention response, and public health: CDC's HIV/AIDS prevention research synthesis project[J]. Public Health Reports, 2022, 137(1): 32-47.

[2] DiMatteo M R, Martin L[R, Haskard-Zolnierek K B. Health behavior change and treatment adherence: Evidence-based guidelines for improving healthcare[M]. Oxford University Press, 2025.

[3] Obeagu E I, Obeagu G U, Ede M O, et al. Translation of HIV/AIDS knowledge into behavior change among secondary school adolescents in Uganda: A review[J]. Medicine, 2023, 102(49): e36599.

[4] He N. Research progress in the epidemiology of HIV/AIDS in China[J]. China CDC weekly, 2021, 3(48): 1022.

[5] Marcus J L, Sewell W C, Balzer L B, et al. Artificial intelligence and machine learning for HIV prevention: emerging approaches to ending the epidemic[J]. Current HIV/AIDS Reports, 2020, 17(3): 171-179.

[6] Xiang Y, Du J, Fujimoto K, et al. Application of artificial intelligence and machine learning for HIV prevention interventions[J]. The Lancet HIV, 2022, 9(1): e54-e62.

[7] Sah A K, Elshaikh R H, Shalabi M G, et al. Role of artificial intelligence and personalized medicine in enhancing hiv management and treatment outcomes[J]. Life, 2025, 15(5): 745.

[8] Siuki H A, Peyman N, Vahedian-Shahroodi M, et al. Health education intervention on HIV/AIDS prevention behaviors among health volunteers in healthcare centers: An applying the theory of planned behavior[J]. Journal of Social Service Research, 2019, 45(4): 582-588.

[9] Cao F. Meta-analysis of Short-term Outcomes Between Da Vinci Robotic Surgery and Laparoscopic Surgery in Distal Gastric Cancer Radical Resection[D]. Northwest Minzu University, 2020.

[10] Tian Y L, Sun Y Q, Kang X N, et al. Practical Exploration of Assistant Responsibilities and Operational Norms in Robotic Radical Gastrectomy[J]. Chinese Journal of Gastrointestinal Surgery, 2025, 28(08):937-941. DOI:10.3760/cma.j.cn441530-20250623-00238.