Postprint: Research Advances in Intelligent Robots for Chronic Disease Management in Primary Care

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Abstract

The rising incidence of chronic diseases worldwide poses significant challenges to societal development and individual health. Chronic disease management necessitates long-term treatment and monitoring, imposing specific requirements on patients' lifestyles. With population aging and shifts in lifestyle patterns, the prevention and control of chronic diseases are assuming increasing importance. In recent years, as technological innovation in the medical and healthcare domain has advanced in depth, the application of artificial intelligence-enabled intelligent robots in healthcare has gradually emerged as a key national strategic priority, traditional chronic disease management methods excessively rely on offline interactions between physicians and patients, precluding the maintenance of long-term effective communication and follow-up, and potentially preventing timely detection and monitoring of patient condition changes. Moreover, conventional approaches typically adopt a one-size-fits-all methodology that inadequately accounts for individual patient differences. In view of these limitations, this study proposes to leverage intelligent robots to deliver more convenient and efficient primary-level services. This paper contends that through functionalities such as personalized health management plans, assisted medical diagnosis, and timed medication reminders, intelligent robots can contribute to improving patients' quality of life, alleviating pressure on medical resources, and thereby advancing the development of global intelligent healthcare management.

Full Text

Research Progress of Intelligent Robots in Grassroots Chronic Disease Management

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Abstract: The increasing prevalence of chronic diseases globally poses major challenges to societal development and individual health. Managing chronic diseases requires long-term treatment and monitoring, placing significant demands on patients' lifestyles. With population aging and lifestyle changes, chronic disease prevention and control are becoming increasingly critical. In recent years, as scientific and technological innovation in healthcare has advanced in depth, the application of artificial intelligence-powered intelligent robots in the medical field has gradually become a key national strategic direction. Traditional chronic disease management methods rely too heavily on offline communication between doctors and patients, making it difficult for physicians to maintain long-term effective communication and follow-up with patients, and preventing timely detection and monitoring when patients' conditions change. Moreover, traditional approaches typically employ generalized methods that fail to adequately account for individual patient differences. Given these limitations, this study aims to leverage intelligent robots to provide more convenient and efficient primary care services. This paper argues that through personalized health management plans, assisted medical diagnosis, and timed medication reminders, intelligent robots can improve patients' quality of life, reduce pressure on healthcare resources, and promote the development of intelligent healthcare management globally.

Key words: Intelligent robots; Primary care; Chronic disease; Health management; Artificial intelligence; Health big data

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1. Overview of Intelligent Robot Development

Intelligent robots are technological products that combine artificial intelligence with autonomous learning capabilities, enabling them to simulate and execute human cognition and behavior, interact with humans, and complete designated tasks. The deep integration of artificial intelligence with Internet+, big data, and 5G technologies has endowed intelligent robots with enhanced perception and decision-making capabilities through powerful computing power, making them more flexible, dexterous, and versatile, with stronger environmental adaptability to handle increasingly complex and variable application scenarios [8].

In December 2021, China released the "14th Five-Year Plan for Robot Industry Development" [9], which outlined a blueprint for the current robot industry and proposed new development goals to further advance China' s robot industry to new heights. Currently, intelligent robots are mainly divided into two categories: household service robots, specifically designed to provide services and educational assistance; and medical robots, including surgical robots, rehabilitation robots, nursing assistant robots, and logistics robots, which can perform a series of tasks in the medical field such as surgery, rehabilitation, and drug delivery [10].

Compared with traditional medical methods, medical intelligent robots are less affected by subjective factors, offer higher diagnostic efficiency, and can perform relatively repeatable operations with minimal impact from environmental conditions and fatigue levels. The combination of intelligent robots with artificial intelligence technology can make grassroots chronic disease management more intelligent and personalized. Many scholars are exploring how to leverage technology to manage grassroots chronic diseases and build a new comprehensive health service system covering chronic disease prevention, control, diagnosis, treatment, recovery, and health management.

2. Problems and Current Status of Grassroots Chronic Disease Management

Chronic disease management refers to the treatment of long-term conditions that are difficult to cure completely, such as diabetes (endocrine system diseases), hypertension (cardiovascular and cerebrovascular diseases), heart disease, and chronic obstructive pulmonary disease (respiratory system diseases). Grassroots chronic disease management is crucial for reducing patients' medical burden. It is estimated that among patients requiring medical services, only about 10% need specialist treatment, while 80%-90% of health problems can be addressed by community health service staff (including community health managers and trained general practitioners) [11]. However, numerous shortcomings exist in current approaches.

Traditional chronic disease management primarily relies on offline communication between doctors and patients. However, due to the large number of grassroots patients and limited medical resources in China, doctors struggle to maintain long-term effective communication and follow-up with all patients [12]. Additionally, grassroots health service centers in China face problems such as single-form management, outdated measures, and a lack of standardized management experience for health information [13]. Chronic disease management requires adequate funding support [14-15], but grassroots medical institutions face insufficient funding, inadequate special fund allocation, and poor fund management, which have become important obstacles to in-depth chronic disease management [16].

Research by Shi Jianhua et al. [17] shows that community hospitals face a se-

ries of challenges including staff shortages, low education levels, limited clinical experience, inadequate technical capabilities and service capacity, and delayed knowledge updates among general practitioners [18]. Residents' distrust of community health service centers' medical standards also leads to reduced first-visit rates. Meanwhile, due to insufficient staffing at grassroots medical institutions, attention must also be paid to whether follow-up visits after establishing health records are comprehensive and authentic [19]. Furthermore, traditional chronic disease management suffers from information asymmetry between doctors and patients—patients typically only receive doctors' guidance during medical visits, and must rely on themselves and their families to manage their conditions between visits, leading to insufficient continuity and stability in disease management. In summary, current grassroots chronic disease management has many limitations that require new methods and technologies to address.

3. Applications of Intelligent Robots in Grassroots Chronic Disease Management

The continuous development of artificial intelligence, 5G, and "Internet+" technologies has expanded the application scope of intelligent robots in grassroots chronic disease management. Intelligent robots can use sensors to monitor patient conditions and provide nursing services according to pre-set algorithms and rules, reducing the burden on medical staff while providing patients with more convenient and comfortable care experiences. For example, intelligent pillboxes (medication management systems) can not only remind patients to take medication on time and calculate remaining dosages, but also help patients with physical assistance for rehabilitation [20]. Nowadays, the application of intelligent robots has expanded to chronic disease management, where they can be integrated with intelligent voice outbound call systems to help patients improve self-disease management capabilities, reduce the workload of medical staff, and enhance patients' quality of life. Technological innovation has brought numerous conveniences to chronic disease management, offering more possibilities for health management and medical services for chronic disease patients [21].

3.1 Health Education and Health Promotion The "Healthy China 2030" Planning Outline issued by the Central Committee of the Communist Party of China and the State Council in October 2016 [22] emphasized the importance of popularizing healthy lifestyles and strengthening health education, highlighted the role of families and high-risk individuals in disease prevention, and incorporated health education into the education system. Health education plays a vital role in chronic disease management by improving patients' disease awareness and cultivating health management capabilities. China' s grassroots health human resources are insufficient, and community and township residents often struggle to receive adequate health education and promotion. Artificial intelligence technology can solve the problem of patients being unable to participate in health management learning anytime due to time and space constraints, effectively improving patient participation rates. By leveraging AI, virtual reality,

cloud computing, and big data analysis, intelligent robots can disseminate the latest disease-related knowledge and health education to community residents, helping them better understand and manage their health conditions and change unhealthy habits [23].

The combination of AI technology with the dual-contracting family doctor model can improve self-management levels among community hypertension patients while increasing visit rates, blood pressure control rates, and compliance [24]. Research has shown that self-management support is the most effective method for chronic disease management [25], indicating that improving patient self-management support levels is very helpful for alleviating pressure on grassroots medical services.

3.2 Remote Medical Support Currently, ultrasound diagnosis plays an indispensable role in medical diagnosis, yet limited ultrasound diagnostic resources at grassroots hospitals often struggle to meet patient needs. To address this issue, remote ultrasound technology has been introduced and widely applied clinically. This technology enables the 下沉 of expert resources to provide higher-quality services for grassroots patients and has extremely high clinical application value [26]. Intelligent robots can serve as tools for remote medical care, allowing doctors to perform remote diagnosis and treatment through robotic operation, thereby providing high-quality medical services for community residents. One study used intelligent robots carrying 5G transmission technology to conduct remote ultrasound assessments of patients, and the diagnostic results were verified to be completely consistent with CT scan results [27].

3.3 Social Support and Psychological Counseling China' s community-based chronic disease management, particularly in mental health, has shortcomings. Grassroots nursing staff have relatively insufficient awareness and training in mental health issues, lacking professional knowledge and skills to effectively address patients' mental health needs. Intelligent robots can provide 24/7 services, offering psychological support anytime and anywhere to relieve patients' anxiety, stress, and other negative emotions. Research shows that using the seal-like robot PARO for intervention can improve the psychological state of dementia and chronic pain patients [28], and social support and psychological counseling can help chronic disease patients alleviate negative emotions, increase treatment adherence, and improve quality of life [29-30].

Intelligent robots can analyze patients' physiological data in real time, record their emotions, and communicate and interact with patients to provide emotional support and psychological counseling, thereby reducing mental stress and loneliness caused by disease while improving quality of life and treatment outcomes [31-32]. For example, the Paro companion robot developed by Japan' s National Institute of Advanced Industrial Science and Technology can help elderly people reduce loneliness and improve social skills; NEC Corporation' s PaPeRo robot features advanced facial recognition, can notify users to receive

instant messages, and can send video messages, perform dances, play games, and remotely control other electronic devices [33-34]. These products are equipped with advanced voice processing and recognition systems that can accurately understand and parse multiple dialects, enabling barrier-free communication between patients and robots.

3.4 Daily Care Assistance As China's population aging deepens, the supply-demand issue for grassroots nursing staff has gradually emerged, and intelligent nursing robots have experienced rapid development. They can provide daily care assistance, effectively reducing the workload of grassroots personnel [35]. Daily care is essential for people with chronic diseases who have limited daily living abilities. Current research and application of rehabilitation robots mainly target patients with neurological damage caused by cerebrovascular diseases [36] and spinal cord injuries [37], helping them recover from long-term sequelae. Through timely and effective rehabilitation training, patients can maximize functional recovery during the optimal recovery period to ensure minimal impact on daily activity capabilities.

3.5 Data Analysis and Prediction Applying intelligent robots in community health surveys can help understand residents' current health needs and existing problems. Additionally, through data analysis and prediction, the prevalence of chronic diseases can be reduced as much as possible, disease risk factors decreased, and disease outbreak risks predicted to help communities better respond to disease outbreaks. AI robots can analyze and mine large amounts of patient data at the micro level to discover relevant patterns and trends, assisting grassroots doctors in better patient management and prevention strategies, though this may also raise security issues such as data privacy breaches. Predicting patients' disease risks can increase their disease awareness and improve medical treatment and follow-up effectiveness [38]. Research shows that applying artificial intelligence for disease risk prediction can effectively improve disease prediction and diagnostic accuracy and promote improvements in patients' quality of life [39-40].

3.6 Diagnostic Assistance Intelligent robots can participate in basic health screening and preliminary diagnosis, including measuring vital signs and performing basic ophthalmology, otolaryngology, and other examinations, helping to detect potential health problems early. Fangzhuang Community Health Service Center in Beijing' s Fengtai District used an AI-assisted decision support system integrated with family doctor contracting, which not only standardized diagnosis and treatment processes but also improved doctors' technical levels [41]. When diagnosing certain diseases early, intelligent robots can provide high diagnostic value. Early symptoms of some chronic diseases are often atypical, making missed diagnoses or misjudgments likely [42-43]. Through advanced algorithms and models, intelligent robots can analyze patients' physiological indicators, genomic data, and other information to provide doctors with early

diagnostic clues and predictions, reducing the risk of delayed diagnosis and patient mortality as much as possible [44], detecting potential health problems earlier and formulating earlier, more effective treatment plans to improve patient survival, which greatly benefits doctors' disease diagnosis.

Intelligent robots also play important roles in remote surgery [45], remote emergency care [46], and remote nursing [47]. After repeated training and learning from large datasets, AI robots have demonstrated higher performance in assessing complex chronic disease etiologies, compensating for limitations in clinical doctors' diagnoses. BUFFOLO et al. [48] found in a large-sample retrospective study that using clinical scoring systems and machine learning could effectively predict primary aldosteronism (PA) patients among those with hypertension, reducing screening workload by at least 32.7% and decreasing unnecessary consumption of medical resources. JIA Weiping [49] developed the DeepDR system that can detect and identify microaneurysms and small hemorrhages, accurately detecting subtle changes in diabetic retinopathy and providing strong technical support for early disease intervention.

3.7 Risk Factor Intervention Intelligent robots can participate in risk factor intervention through multiple approaches, including changing individuals' lifestyle behaviors, living environments, or related social factors to reduce disease risk or improve patient health status. Robot systems can collect information on patients' lifestyle habits and health data, and provide specific treatment suggestions and corresponding intervention measures based on analysis results to reduce related disease risks [50]. Intelligent robots can also provide patients with personalized diet plans, regular exercise schedules, and medication guidance.

3.8 Personalized Health Management The Wuhan Dongxihu District Health Commission uses the "Smart Medical Assistant" platform to regularly release health management tasks to community doctors and intelligently remind medical staff to complete daily chronic disease management services for residents [51]. This initiative not only significantly reduces the daily workload of grassroots medical staff but also enhances the service capacity of grassroots medical institutions, effectively promoting the improvement of grassroots medical informatization. In the 5G era, AI can monitor patients' health status in real time by combining deep learning models with high-performance computing, and transmit data to medical equipment for analysis and evaluation. Intelligent robots can record patients' daily behaviors, including sleep duration, exercise volume, and diet records, and use data analysis and intelligent algorithms to provide personalized intervention measures [52], helping patients improve unhealthy behaviors and promoting rehabilitation and disease management [53]. Intelligent robots can tailor personalized health management plans based on patients' physical conditions and individual needs. By collecting and analyzing patients' physiological data, daily habits, and relevant medical histories, they can assist people with chronic diseases in managing their conditions more

effectively [54]. Related studies show that intelligent robots can automatically send reminder messages to diabetic patients based on personalized plans, and such functions can effectively improve chronic disease patients' quality of life, reduce pressure on medical resources, and promote the development of intelligent chronic disease management [55-56]. For example, Next IT' s Alme Health Coach system provides comprehensive assistance for chronic disease patients, including planning daily diets, monitoring sleep quality, reminding medication times, and even deriving reasons for irregular medication adherence through patient data analysis. The system can also build chronic disease dietary recommendation systems suitable for hypertension patients [57]. A visual robot chat architecture can meet patients' needs for physiological data storage, remote monitoring of daily behaviors, and timed medication reminders, while intelligent robots can assist in recording patients' medical information to ensure data accuracy and timeliness, which is very important for community hospital information management and health record maintenance [58-59].

4. Challenges and Prospects for Medical AI Development

Technological advances in AI and medicine have brought new possibilities for solving traditional chronic disease management problems. However, intelligent robots face many difficulties in grassroots chronic disease management:

(1) **Intelligent robots cannot completely replace medical staff.** Although AI programs can monitor vital signs and perform basic nursing tasks, they focus more on maximizing patient treatment benefits while neglecting humanistic care for patients' inner needs [60]. Humanistic care from medical staff is indispensable. Intelligent robots need to accurately understand user instructions, execute them smoothly, and maintain good communication with patients to ensure consistent doctor-patient communication. Humanistic care remains a capability that intelligent robots lack [61].

(2) **Data bias issues.** Intelligent robots rely on selected big data for analysis, but dataset establishment by researchers may lead to certain biases in diagnosis and treatment [62]. Additionally, when using algorithms for decision-making, if these algorithms favor certain individuals or groups, they may harm the interests of others and exacerbate unfairness [63].

(3) **Varying patient acceptance.** Due to unfriendly human-computer interaction, many elderly patients are resistant to using robots. Research on Anderson' s health behavior model shows that patients' acceptance of new service models is influenced by factors such as age, gender, region, and knowledge level about chronic diseases [64-65].

(4) **Privacy and data security concerns.** Ensuring that the large amount of personal health data stored by intelligent robots is not attacked or misused by third parties is an issue requiring careful consideration [66].

(5) **High costs.** Although intelligent robots can reduce the burden on medical resources to some extent, their popularization and promotion are limited by high costs, and maintaining and updating intelligent robots also requires significant funding [67]. To fully exploit the potential of intelligent robots in chronic disease management, in-depth research and exploration must continue.

(6) **Unclear responsibility 界定 in doctor-patient relationships.** Responsibility boundaries should be clarified for delayed diagnosis and misdiagnosis caused by intelligent robot program errors [68].

In the future, intelligent robots will be widely used in the medical field. They will serve as doctors'assistants, helping with diagnosis, monitoring patient health status, and providing personalized treatment recommendations. During surgery and treatment, they will provide precise support while improving doctor-patient communication and enhancing medical service efficiency and quality. With technological progress, intelligent robots are expected to become important assistants in the medical field, promoting medical level improvements and better utilization of medical resources.

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