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Integrating Artificial Intelligence into the Diagnosis of Neurological Diseases in Traditional Chinese Medicine

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Abstract: Traditional Chinese medicine (TCM) uses a holistic approach and syndrome differentiation to diagnose neurological disorders. However, traditional diagnostic methods—which rely heavily on subjective clinical experience—lack objective standardization. This paper reviews the transformative application of artificial intelligence (AI) in modernizing TCM diagnostics for neurological diseases. By integrating advanced technologies such as machine learning (ML), deep learning (DL), and natural language processing (NLP), AI provides unprecedented objectivity and precision. Current applications demonstrate significant breakthroughs, notably in the use of deep learning to analyse extensive clinical records for automated syndrome differentiation (e.g., stroke patients) and the use of image recognition for automated tongue diagnosis. These innovations are shifting TCM from an experience-dependent paradigm to a data-driven model. Looking forward, the future of AI in TCM neurology hinges on multimodal data fusion, which integrates imaging, tongue, pulse, and clinical data to digitally reconstruct the TCM diagnostic process. Furthermore, developing explainable AI (XAI) is critical to overcoming the "black box" dilemma, thereby fostering clinician trust. The widespread deployment of these intelligent systems via cloud computing holds immense potential for grassroots healthcare, although it necessitates robust ethical and legal frameworks to ensure data privacy. Ultimately, AI significantly accelerates the scientific validation of TCM, paving the way for personalized and precision medicine in treating neurological conditions.

Keywords: Traditional Chinese medicine; Artificial intelligence; Neurological disorders

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1. Introduction

The rapid advancement of artificial intelligence (AI) and its widespread application in medical diagnostics have demonstrated tremendous potential, particularly in the diagnosis and management of neurological disorders within the framework of traditional Chinese medicine (TCM). As a medical system with a millennial history, TCM emphasizes a holistic concept and treatment based on syndrome differentiation (Bian Zheng Lun Zhi). In light of modern medical technologies, TCM diagnostics can now achieve unprecedented objectivity and precision. In recent years, the integration of AI technologies—such as machine learning and deep learning—into research on TCM-based neurological disorders has effectively increased disease recognition rates and diagnostic efficiency [1]. By analysing traditional diagnostic data, such as pulse and tongue manifestations, and coupling them with AI algorithms, it is possible to achieve reliable computer-aided diagnosis for neurological conditions such as stroke and cerebral infarction [2]. Furthermore, AI plays a pivotal role in TCM data mining, disease prediction, and the formulation of personalized treatment regimens, thereby providing novel technical support for the research of neurological disorders in TCM. This paper aims to review the current application status, key technologies, and future trajectories of AI in the diagnosis of TCM-related neurological diseases, serving as a comprehensive reference for subsequent research.

2. Diagnostic characteristics and current status of TCM

Guided by a holistic philosophy, traditional Chinese medicine (TCM) emphasizes "syndrome differentiation and treatment" (*Bianzheng Lunzhi*). Common neurological disorders such as stroke (termed *Pianku* in TCM), epilepsy (*Xianzheng*), and neurasthenia (associated with *Bumei*, *Xulao*, or *Yuzheng*) are primarily driven by pathological mechanisms, including the internal stirring of liver wind, obstruction of collaterals by phlegm and blood stasis, and deficiency of qi and blood [3]. These diseases are characterized by complex pathogenic mechanisms, diverse clinical manifestations, an interplay of acute and chronic features, and highly variable pathogenesis [4]. The diagnostic system of traditional Chinese medicine (TCM) emphasizes the integration of four diagnostic methods: inspection, auscultation and olfaction, inquiry, and palpation. This comprehensive approach incorporates specific diagnostic techniques, such as tongue and pulse diagnosis, as well as facial complexion, body posture, and tongue coating [5]. The successful application of these methods requires extensive clinical experience. Because the diagnostic process relies deeply on the subjective judgment of the practitioner, it often exhibits substantial subjectivity and a lack of interrater consistency [6]. Moreover, traditional techniques such as tongue and pulse diagnosis lack objective, quantitative indicators, making their standardization and digitization highly challenging [7]. Additionally, when complex and variable neurological diseases are confronted, traditional diagnostic modalities struggle to comprehensively reflect underlying pathological changes and are susceptible to external environmental factors and individual variations [8]. Although the continuous advancement of modern technologies—such as medical imaging and neuroelectrophysiology—can yield objective disease data, seamlessly integrating these modalities into the TCM syndrome differentiation system remains a persistent challenge [9]. The inherent limitations of traditional diagnostic methods pose notable challenges for the use of TCM in the diagnosis of neurological diseases. Therefore, leveraging modern technology is imperative for enhancing the objectivity and accuracy of diagnosis, ultimately unlocking new diagnostic possibilities for neurological disorders within the TCM framework.

3. Overview of artificial intelligence technologies

The rapid advancement of artificial intelligence (AI) in the medical field has driven profound transformations in disease diagnosis, treatment formulation, and health management. Core AI technologies—primarily machine learning (ML), deep learning (DL), and natural language processing (NLP)—are being integrated into medicine in depth, providing novel technical methodologies for the diagnosis of neurological disorders.

Machine learning is a technology that enables computers to automatically learn models from vast amounts of data to perform predictions and classifications. Through algorithmic optimization, ML can recognize complex patterns and is widely applied in medical image analysis, disease prediction, and risk assessment [4]. In the diagnosis of neurological diseases, ML models such as support vector machines (SVMs) and random forests have been utilized for neuroimaging analysis and disease classification [10]. Furthermore, deep learning uses multilayered neural networks to simulate the structure of human brain neurons and has a robust capacity for automatic feature extraction. For instance, deep convolutional neural networks (CNNs) can automatically identify minute structural changes in brain MR and CT images, effectively improving the diagnostic accuracy for neurological diseases and demonstrating immense potential in the early diagnosis of conditions such as epilepsy and Alzheimer's disease [11–12]. Additionally, NLP technology enables computers to understand, analyse, and generate natural language text. In medicine, NLP is employed for extracting information from electronic medical records, literature mining, and clinical decision support [13]. Within the neurological domain, NLP assists in organizing patients' clinical descriptions and extracting key symptom information, thereby providing vital support for computer-aided diagnosis [14].

The application of AI in medicine has expanded beyond auxiliary image analysis to encompass multimodal data fusion, personalized prediction, and intelligent decision support [4]. Particularly in the diagnosis of neurological diseases, the integration of AI with neuroimaging, genomic information, and clinical data significantly enhances the accuracy of early disease recognition and diagnosis. For example, the application of DL models to brain MRI detection has substantially improved diagnostic precision [12]. Moreover, combining NLP techniques with the analysis of electronic health records enables the rapid screening of potential neurological patients, providing a solid evidence base for early intervention [13].

4. Application of AI in the diagnosis of TCM-related neurological diseases

With rapid technological advancements, the application of AI in the diagnosis of neurological diseases within traditional Chinese medicine (TCM) has continued to increase, advancing the modernization and scientific validation of the TCM diagnostic framework. A research team from Taiyuan University of Technology collected traditional TCM medical records from 1,134 stroke patients for deep learning analysis [14]. The study embedded the diagnostic logic of TCM's "Six-Meridian Syndrome Differentiation" (*Liu Jing Bian Zheng*), encompassing syndrome types, symptoms, treatment modalities, and prescriptions. The results indicated that the diagnostic accuracy for four syndrome types—Taiyang, Yangming, Shaoyin, and Jueyin—exceeded 80%. However, the accuracy for Shaoyang and Taiyin syndromes fell below 80% because their representation accounted for less than 10% of the total sample size. These findings demonstrate that an adequate volume of medical records, coupled with machine deep learning, can effectively increase the diagnostic efficiency of TCM and assist practitioners in the rapid identification of syndrome types. In the long term, by strengthening case databases to include imaging, clinical symptoms, and treatment plans, and by combining these with ML model training, intelligent prediction and risk assessment for the TCM management of neurological diseases can be realized.

Furthermore, AI analytical models for tongue diagnosis are being gradually established that utilize image recognition technology to extract features of the tongue coating to assist in syndrome differentiation and treatment. One study focusing on tongue images of stroke patients aimed to improve the accuracy of automatically extracting and recognizing stroke-related tongue features through image processing and ML techniques [15]. Considering that tongue shape, color, and texture reflect the body's physiological and pathological states in TCM theory, a labelling and recognition system was designed. The model learned to automatically identify key features such as tongue shape, color, and texture, with the results showing an average diagnostic accuracy exceeding 81%.

The current breakthroughs in the use of AI for syndrome differentiation indicate that TCM is transitioning from a traditional "experience-dependent" paradigm to a "data-driven" model. In the future, with the establishment of comprehensive databases and the capture of constitutional features in high-risk populations, AI could issue early warnings during the latent stages of neurological diseases (e.g., Alzheimer's disease and stroke precursors). This aligns perfectly with the core TCM philosophy of "preventive treatment of disease" (*Zhi Wei Bing*).

5. Future development trends and prospects

With the continuous maturation of artificial intelligence (AI) technology, its application in the diagnosis of neurological diseases within TCMs has broad prospects. Future technological breakthroughs will focus primarily on multimodal data fusion and the optimization and validation of deep learning models. At the data level, a "panoramic" diagnostic approach that integrates multisource information—such as medical imaging, tongue manifestations, and pulse conditions—is essentially a digital reconstruction of TCM clinical reasoning based on the "Four Diagnostic Methods." The bottleneck for future breakthroughs lies in dynamic feature weight allocation algorithms (e.g., scientifically evaluating the relative importance of pulse conditions versus gait videos in the diagnosis of tremor syndrome, or Chan Zheng), which are essential for comprehensively enhancing diagnostic accuracy and reliability [16–17]. At the model level, in addition to introducing cutting-edge algorithms such as transfer learning and conducting multicenter, large-sample clinical trials to verify model stability, the development of explainable AI (XAI) is particularly crucial [18–19]. To prevent clinicians from falling into the dual dilemma of the TCM "experience black box" and the deep learning "algorithm black box", AI must possess logical traceability. By displaying the derivation basis alongside the final syndrome type conclusions, AI can truly earn the trust of physicians, assist in clinical teaching, and achieve a steady translation from technological innovation to clinical utility.

Building upon these technological breakthroughs, the scalable application of intelligent TCM diagnostic systems and the establishment of related ethical and legal frameworks constitute another core focus of future development. With respect to clinical promotion, the integration of cloud computing and the mobile internet will enable intelligent systems to not only alleviate the burden on medical staff and promote the standardization of TCM diagnostics but also facilitate deployment in grassroots medical institutions [20]. By accessing top-tier AI expert systems via the cloud, grassroots physicians can effectively construct an integrated "home-community-hospital" network for the screening and chronic disease management of neurological conditions (such as stroke sequelae). However, in the preliminary stages of comprehensive system implementation, paramount importance must be attached to data privacy and medical ethical risks [21]. Faced with the latent dangers of the use of highly sensitive biometric data (e.g., facial and tongue images), as well as the ambiguous attribution of legal liability in cases of AI misdiagnosis or "doctor–machine opinion conflicts", the industry urgently needs to formulate strict security standards and establish a liability division mechanism tailored specifically for AI-assisted healthcare. Only by operating within a compliant and transparent legal and ethical framework can a virtuous cycle be ensured for the application of AI technologies in the diagnosis and treatment of TCM-related neurological diseases.

6. Conclusion

The development and maturation of AI technology have demonstrated immense potential and broad prospects for its application in the diagnosis of TCM-based neurological diseases. By integrating advanced technologies such as machine learning, deep learning, and natural language processing, researchers have achieved significant milestones in image recognition, syndrome analysis, case database construction, and the formulation of personalized treatment plans. These innovative applications not only increase the efficiency and accuracy of the diagnosis of TCM-related neurological diseases but also propel the modernization and scientific validation of the TCM diagnostic framework, providing novel technological support for the inheritance and development of traditional medicine. Looking ahead, advancing AI research in this field requires a sustained focus on multimodal data fusion—combining imaging, tongue diagnosis, pulse diagnosis, and genomic information—to construct panoramic and multidimensional diagnostic models [22]. Concurrently, multicenter, large-sample clinical validations are imperative to ensure the stability and practical utility of these models. Furthermore, promoting legislative development and ethical oversight to safeguard patient privacy and data security will provide the necessary institutional guarantees for the widespread application of AI in TCM neurology. In summary, AI holds tremendous development potential and application value in this domain. Future research will significantly accelerate the modernization of TCM, drive the evolution of personalized and precision medicine, and provide robust technical support for improving therapeutic outcomes in patients with neurological diseases.

Ultimately, the trajectory of AI in diagnosing neurological diseases will pivot toward multisource data fusion, enhanced model explainability, and seamless clinical translation. Multimodal learning involves the synthesis of imaging, genomic, and clinical data to yield a more comprehensive delineation of disease phenotypes. Simultaneously, model explainability will remain a paramount research focus to bolster clinicians' trust and foster broader clinical acceptance. Moreover, catalyzed by the proliferation of edge computing and cloud computing, AI diagnostic tools will become increasingly ubiquitous, vigorously propelling the advancement of personalized healthcare.

Disclosure statement

The author declares no conflict of interest.

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