

Promoting the Intelligent Transformation of TCM Diagnosis and Treatment for Smart Health and Elderly-Care: A Systems-Engineering Perspective

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Abstract: Driven by accelerating global population aging and the thorough roll-out of the Healthy China 2030 Strategy, the smart health and senior-care industry has evolved into a critical pillar for protecting the health and quality-of-life of hundreds of millions of elderly individuals. A precious heritage of China, traditional Chinese medicine (TCM) offers unique merits in elderly chronic-disease management, functional retention and holistic health, serving as a core pillar of healthcare for older adults. The intelligent transformation of TCM diagnosis and treatment is currently constrained by a single-technology bottleneck, which necessitates a systems-engineering approach to deliver breakthrough advances. This paper proposes a transformation framework for TCM diagnosis and treatment covering the perception, cognitive, execution, and ecosystem layers, discusses the elements and conditions of standards, talent, policies, and offers solutions to current challenges such as insufficient sensor accuracy, difficulties in computing TCM knowledge, shortage of cross-disciplinary interdisciplinary talent, and data silos. This study aims to propose actionable pathways for the digital-intelligent transformation of TCM diagnosis and treatment, thereby supporting the high-quality development of the smart health elderly-care industry.

1. Introduction

China is currently in an accelerated phase of population aging. According to data from the National Bureau of Statistics, by the end of 2024, China's population aged 60 and above reached 310 million, accounting for 22.0% of the national population, among whom 220 million were aged 65 and above, accounting for 15.6% of the total population [1]. According to statistics from the National Health Commission, approximately 190 million elderly people in China suffer from chronic diseases. The elderly are confronted with severe challenges brought by multiple comorbidities and difficulties in health management.

As population aging continues to deepen, the smart health and elderly-care industry is growing in

importance. In June 2025, the Ministry of Industry and Information Technology and the Ministry of Civil Affairs jointly issued a notice to carry out pilot applications of smart elderly-care service robots in households, communities, and elderly-care institutions. In January 2026, eight departments including the Ministry of Civil Affairs jointly issued Several Measures for Cultivating Elderly-care Service Operators and Promoting the Development of the Silver-hair Economy. The document explicitly proposes strengthening the digital-intelligent upgrading of elderly-care services and applying big data, cloud computing, artificial intelligence, and Beidou technology to elderly health monitoring, safety alarms, and personalized customized services [2]. Industrial policies provide strong institutional guarantees and directional guidance for the development of the smart health and elderly-care.

Among various health-care and elderly-care solutions, TCM diagnosis and treatment, with its unique theoretical system and practical advantages, has increasingly become a key force for coping with aging-related challenges. Emphasizing the holistic concept and the idea of "preventing diseases before their onset", TCM diagnosis and treatment follow the full-cycle management philosophy of "preventing diseases before they occur, arresting diseases before they deteriorate, and preventing the transmission of existing diseases", which is highly consistent with the systematic requirements of elderly health management. Meanwhile, TCM appropriate technologies are characterized by simplicity, convenience, effectiveness and low cost, making them highly suitable for home-based and community-based elderly-care scenarios. Nevertheless, the intelligent transformation of TCM diagnosis and treatment still face difficulties such as the contradiction between inheriting traditional experience and pursuing modernization and standardization; and the need to enhance scientific and technological discourse influence amid global competition. Digital-intelligent development represents the inevitable path to address these issues [3].

2. TCM-based diagnosis and treatment is an indispensable pathway for high-quality development in the smart health and elderly-care

2.1 Analysis of Smart Health and Elderly Care Needs

The elderly population generally suffers from compound health problems including multiple comorbidities, functional degeneration, and the imbalance of both physical and mental states. In clinical practice, the elderly often manifest the constitutional characteristic of "root deficiency and branch excess". Root deficiency refers to insufficiency of qi, blood, yin and yang, while branch excess refers to accumulation of phlegm, blood stasis and dampness. Clinically, comprehensive therapeutic approaches of "strengthening healthy qi and eliminating pathogenic factors" are required. Such complexity and dynamics mean that elderly-care health services cannot stay at the level of partial symptomatic treatment such as "treating the head when the head hurts and treating the feet when the feet hurt". Instead, systematic and holistic intervention schemes are indispensable.

Traditional elderly-care models have obvious deficiencies in chronic disease management and personalized care. Li Jie, Member of the National Committee of the Chinese People's Political Consultative Conference and President of Guang'anmen Hospital, China Academy of Chinese Medical Sciences, pointed out that we should support the in-depth application of artificial intelligence technology in fields including TCM diagnosis-treatment equipment, elderly functional assistance and health-monitoring management. It is necessary to build open-sharing platforms, gather multidisciplinary strengths to jointly tackle core technologies and "bottleneck-restricting" challenges in geriatric health, and guide the high-quality development of domestic smart health and elderly-care industry through improving the elderly health service system [4][5].

2.2 The unique value of TCM diagnosis and treatment for elderly health

First, holistic medical thinking conforms to the demands of elderly health management. Guided by the theories of "harmony between human and nature" and "co-regulation of body and spirit", TCM diagnosis and treatment regard the human body as an organic whole and formulates therapeutic plans by comprehensively considering environmental, psychological and physiological factors, which is highly consistent with the systemic requirements of elderly health management.

Second, low-cost and high-efficiency service modes are adaptable to elderly-care scenarios. TCM appropriate technologies do not rely on large-scale equipment and feature low costs, which can effectively reduce the financial burden on the elderly. This service model of "integration of prevention, treatment and health preservation" significantly improves the accessibility and cost-effectiveness of elderly-care services.

Third, TCM constructs a three-level prevention system covering the whole life cycle. From constitution identification and personalized health preservation, to early intervention for sub-health conditions, and further to collaborative diagnosis-treatment and rehabilitation for chronic diseases, TCM diagnosis and treatment have built a complete prevention-intervention-rehabilitation chain. For instance, Guangwai Hospital of Beijing has launched the "Five-Dimension" holistic system service model for TCM-based elderly-care. Through systematic coordination of five dimensions — examination, evaluation, therapy, control and management — it realizes full-life-cycle TCM diagnosis-treatment services for the elderly [6].

2.3 Complex System of Intelligent Transformation in TCM Diagnosis and Treatment

The fundamental reason why the intelligent transformation of TCM diagnosis and treatment requires the methodological framework of complex-systems engineering lies in the inherent complexity of the TCM knowledge system. The core of intelligence is to build a technical closed-loop characterized by theorization for computation, multi-modal perception, interpretable decision-making and adaptive execution. Specifically, classical TCM diagnosis-treatment theories are transformed into computable correlation networks via knowledge graphs; the objective quantification system of four diagnostic methods is reconstructed with modern scientific-technological means; and dynamic revision of syndrome-differentiation decisions is realized based on hybrid augmented intelligence.

At the theoretical level, TCM's unique four-diagnosis method of observation, listening-smelling, inquiry and pulse-taking and its core principle of treatment based on syndrome differentiation require intelligent decision-making logic to follow syndrome-differentiation rather than merely symptomatic treatment. At the perception level, high-sensitivity sensors are required to capture the manifestations needed for traditional observation-based diagnosis and pulse diagnosis. At the cognition level, deep-learning and pattern-recognition technologies need to parse health-state features embedded in facial complexion, tongue coating and pulse conditions. At the execution level, high-precision positioning and dexterous operating systems must offer reliable support for acupoint stimulation and manipulative operations. At the inheritance level, massive knowledge graphs, as digital carriers of TCM thinking, are endowed with powerful capabilities for logical reasoning and scheme generation.

Notably, the syndrome-differentiation thinking and individualized intervention logic guided by the TCM holistic outlook provide a valuable paradigm for overcoming the existing limitations of AI-enabled healthcare: over-emphasis on data while neglecting logic, and over-emphasis on local parts while neglecting systems. This fundamentally explains why the intelligent transformation of TCM diagnosis and treatment is more than simple digitalization and automation, turns into a genuine complex-systems engineering project.

2.4 The intelligent transformation of TCM diagnosis and treatment has shifted to system integration

Due to the complex-system, the intelligent transformation of TCM diagnosis and treatment cannot be achieved through single-point technological breakthroughs; it must follow the path of system integration. At present, multiple innovative practices have emerged across regions. Fuzhou City in Jiangxi Province has built an intelligent auxiliary diagnosis system for basic TCM diagnosis and treatment, and many TCM hospitals have introduced intelligent devices such as TCM four-diagnosis instruments. Research teams promote iterative R&D for intelligent heat-sensitive moxibustion, and smart shared TCM pharmacies have been put into operation in many regions. Hunan's "Three-intelligence and Three-linkage" service model — namely, smart diagnosis-treatment with urban-rural upper-lower linkage, smart pharmacy with medicine-therapy integration, and smart management with policy linkage — has been implemented on a pilot basis in Changsha, Hengyang, Shaoyang and other cities. To date, its cumulative service volume has exceeded 320,000 person-visits, of which more than 90,000 person-visits correspond to auxiliary TCM diagnosis-treatment services for older adults [7].

Intelligent transformation is not simply stacking technical modules onto conventional TCM services, but demanding continuous advancement under a complex-engineering framework featuring multidisciplinary collaboration, systematic integration and full-process optimization. From sensor R&D at the intelligent perception layer, to big-data modeling and algorithm design at the cognition layer, to precise intelligent operations at the execution layer, and to service-process re-engineering and ethical-norm construction at the management layer, every layer is deeply coupled with the theoretical system. The coordination of these elements guided by complex-systems-engineering thinking enables the deep integration and high-quality development of TCM diagnosis-treatment and smart health-elderly-care.

3. System engineering architecture for the intelligent TCM diagnosis and treatment

3.1 Theoretical Foundation of the Holistic View in TCM

Complex-systems theory holds that the overall behavior of a system cannot be understood through simple superposition of its components; instead, attention should be paid to the interactions and emergent effects among system elements [8]. The holistic concept of TCM has an in-depth intrinsic consistency with this theory: the human body is an organic whole composed of multi-system, multi-level and multi-dimensional interactions, and the occurrence and progression of diseases are external manifestations of this dynamic imbalance. Essentially, the intelligent transformation of TCM diagnosis and treatment represents a leap from single-technology application to a systematic technological ecosystem.

The systematic development of TCM intelligence is rooted in the two-way empowerment between theoretical standardization and engineering-technological innovation. The former addresses the algorithmic challenges of syndrome-differentiation logic, while the latter provides hardware support for the objectification of the four diagnostic methods. Together they form the theoretical foundation and tool-chain guarantee for technology implementation. As the AI-driven Fourth Industrial Revolution reshapes the global medical landscape, the modernization transformation of TCM diagnosis and treatment is embracing this dual opportunity.

3.2 Technical Architecture of a Multi-Level Intelligent System for TCM Diagnosis and Treatment

The intelligent transformation of TCM diagnosis and treatment requires building a technical architecture consisting of four layers: intelligent perception layer, intelligent cognition layer, intelligent execution layer, and smart health-care ecosystem.

The intelligent perception layer is the fundamental link for data collection and information acquisition, dedicated to digitalizing "observation, listening-smelling, inquiry and pulse-taking". Specifically, intelligent tongue-diagnosis and facial-diagnosis systems adopt multispectral imaging and convolutional neural-network algorithms to construct quantitative indicator systems for tongue manifestations and facial complexion under standardized light-source conditions, breaking the subjective limitations of traditional visual diagnosis. In the objectification of pulse diagnosis, flexible sensor arrays dynamically capture multi-dimensional pulse waveforms under superficial, middle and deep probing pressures, and temporal-sequence modeling algorithms are employed to analyze pulse-condition features. Intelligent inquiry interaction combines speech recognition and natural-language-processing technologies to develop structured dialogue models embedded with TCM syndrome-differentiation thinking. TCM four-diagnosis intelligence adopts the innovative design of "TCM theories + artificial intelligence + big data" to realize standardization of four-diagnosis procedures, visualization of tongue, facial and pulse information, and intellectualization of diagnostic analysis [9].

The four-diagnosis intelligent system developed by Professor Dong Changwu from the Second Affiliated Hospital of Anhui University of Chinese Medicine has been deployed in more than 200 medical institutions nationwide. At the Wannianbo Sub-district Community Health Service Center in Hefei, residents can complete rapid health check-ups covering more than 500 health states within 10 seconds by using relevant intelligent devices [10]. The digital-intelligent TCM four-diagnosis instrument jointly developed by Xiyuan Hospital of China Academy of Chinese Medical Sciences and the Institute of Microelectronics, Chinese Academy of Sciences achieves a diagnostic consistency rate of over 80 %. The Hyperspectral Observation-diagnosis Analyzer, independently developed by Professor Yang Zhaohua's team at Beihang University, can synchronously collect facial and tongue hyperspectral images across 60 wave bands within one second and extract 376 quantitative parameters in accordance with TCM diagnostics theories [11].

The intelligent cognition layer undertakes fusion analysis and intelligent decision-making for multi-modal data collected by the perception layer. By constructing massive knowledge graphs and deep-learning models, the system can identify syndrome patterns from multi-dimensional data including tongue manifestations, pulse conditions and facial complexion, and generate individualized syndrome-differentiation schemes. At present, the industry has launched the Three-part Nine-level Pulse Large-model cloud platform built upon multi-modal objectified data. It is capable of outputting professional diagnosis-treatment schemes covering diagnosis, syndrome differentiation, therapeutic principles, prescriptions and health-preservation regimens, providing auxiliary support for TCM telemedicine and grassroots community-based diagnosis-treatment services. The system continuously conducts self-learning and iterative optimization based on real-world clinical data, promoting syndrome-differentiation models toward higher accuracy and reliability.

The intelligent execution layer realizes the precision and automation of TCM diagnosis-treatment operations. The digital TCM meridian-regulating intelligent equipment developed by Zhongke Shangyi is based on the TCM theory of "internal diseases treated by external therapies". It integrates advanced technologies including flexible intelligence, AI vision and intelligent perception to build an intelligent treatment system with coordinated "hands, eyes and

brain"[12]. Equipped with a deep-learning-based panoramic AI vision system, force-sensing dual flexible robotic arms, and a compound conditioning head integrating multi-physical factors of force, heat and magnetism, it can complete meridian-path identification and planning within one second and deliver a single precise conditioning session within 30 minutes. Its KY-3 AI meridian-regulating intelligent device adopts a composite conditioning head integrating force, heat and magnetism, supporting high-speed vibration excitation, constant-temperature thermal fields and targeted magnetotherapy. It has built a "symptom-manifestation-meridian-attribution" intelligent-computing cloud brain to realize full-process closed-loop control over conditioning sites, intensity, depth and duration.

Intelligent moxibustion devices developed by Sichuan Qianli Beikang adopt high-precision sensors and a high-definition 3D vision system to rapidly scan human bodies and deduce acupoint distributions. Robotic arms accurately simulate multiple TCM moxibustion manipulations such as suspended moxibustion, circling moxibustion and sparrow-pecking moxibustion. Combined with a "dynamic compensation algorithm", the therapeutic head automatically adjusts angles following the curvature of the human body surface [13]. The "Sky-eye" health-screening system launched by the Jinguanyi Sub-district Comprehensive Service Center for the Elderly in Jinjiang District, Chengdu captures facial micro-expression data via cameras and performs analysis with AI medical large-models. It can complete more than ten examination items including heart rate, blood oxygen saturation and emotional status within 90 seconds [14].

The smart health-care ecosystem serves as the integration and collaboration platform for the above-mentioned three layers. It covers data-integration platforms, standardization systems, ethical norms, cross-industrial collaboration mechanisms and talent-training systems. This layer shall not only realize interconnection and data sharing among intelligent devices, but also guarantee the sustainable advancement of intelligent transformation from management, policy and cultural dimensions.

3.3 Support Systems for the Intelligent Transformation of TCM Diagnosis and Treatment

3.3.1 Standards and Norm Construction

The intelligent transformation of TCM diagnosis and treatment requires building a unified standard system covering multiple dimensions: terminology standardization, data-interface specifications, equipment interoperability, and service-quality evaluation. The Ministry of Industry and Information Technology has explicitly stated that it will compile and release a construction guide for the standard system of elderly-product industries, and formulate special standards in key fields such as home appliances, consumer electronics and furniture to provide effective guidance for the R&D, production and promotion of age-adapted products [15]. Standard development shall follow the orientation of "international alignment with Chinese characteristics", actively participate in the formulation of relevant standards by international standardization organizations, and enhance China's discourse power and influence in the field of smart health and elderly-care.

3.3.2 Talent-training System

Intelligent transformation demands a large number of compound talents. They should be proficient in both TCM theories and clinical practice, master cutting-edge technologies such as artificial intelligence, big data and robotics, and possess overall planning capabilities for complex-systems engineering. At present, there is a prominent talent gap in this field. It is urgent to build a talent-training system integrating medicine-engineering-information disciplines, establish more open-sharing platforms, and pool multidisciplinary strengths to jointly tackle core-technology

challenges in geriatric health.

3.3.3 Policy and Institutional Guarantees

The intelligent transformation of TCM diagnosis and treatment cannot be separated from top-level design and policy support. In January 2026, the Ministry of Industry and Information Technology further clarified four key tasks: continuously carrying out high-quality elderly-product benefit-elderly and enterprise-supporting actions, stepping up product R&D focusing on the pain points of the elderly, continuously optimizing the construction of standard systems, and further promoting age-adapted transformation of internet applications and intelligent terminals. In the Guiding Opinions on Further Promoting Civil-affairs Scientific and Technological Innovation, the Ministry of Civil Affairs also explicitly proposed vigorously promoting the in-depth integration of elderly-care service technical equipment and products with typical service scenarios including households, communities and institutions, so as to form holistic multi-scenario comprehensive care solutions for the elderly [16].

3.4 The complexity and coordination mechanisms of systems engineering

The systems-engineering characteristics of the intelligent TCM diagnosis and treatment determine that its construction process must follow the fundamental laws of complexity science. The primary dimension of complexity is "systematic integration". There exists inseparable synergy among the perception layer, cognition layer, execution layer and ecosystem. The precision of the perception layer determines the reliability of analysis at the cognition layer; algorithm capabilities of the cognition layer restrict the operational performance of the execution layer; organizational and policy guarantees of the ecosystem influence the breadth and depth of technology implementation. Any shortcoming in any link will trigger the "cask effect", restricting the overall functional performance of the system.

The second dimension of complexity lies in the "global coupling of standards and ethics". Intelligent TCM diagnosis and treatment involve multiple ethical dimensions including health-data privacy protection, algorithm interpretability and doctor-patient trust relationships. These ethical issues are tightly coupled with technical schemes: the more complex the algorithms are, the higher the risks of data security and the greater the difficulty of interpretability. Ethical constraints shall be embedded internally during the design, R&D and deployment stages of systems engineering, rather than attached afterwards.

The third dimension of complexity is in-depth multidisciplinary collaboration. It means not merely collaboration between TCM physicians and engineers, but systematic integration of multiple disciplines including TCM theories, modern medicine, computer science, materials science, robotics and psychology. For instance, the R&D of pulse-diagnosis sensors requires joint efforts of TCM theory, materials science and micro-electromechanical-system (MEMS) technologies. The construction of syndrome-differentiation models demands deep integration of TCM syndrome-differentiation logic, machine learning and data science.

The fourth dimension of complexity is full-lifecycle closed-loop optimization. Intelligent transformation is not a one-off construction task, but a dynamic process of continuous iteration and optimization. From clinical-data collection and analysis, to algorithm optimization and equipment iteration, to service-process reengineering and user-feedback collection, continuous learning and closed-loop feedback mechanisms are required to realize the system's self-evolution.

4. Challenges in the Intelligent Transformation of TCM Diagnosis and Treatment

4.1 Challenges in TCM Diagnostic and Treatment Technology

Technical bottlenecks constitute the primary challenges for the intelligent transformation of TCM diagnosis and treatment. The objectification and standardization of the four diagnostic methods are core obstacles restricting intellectualization. At present, tongue-manifestation and facial-complexion recognition in observation-based diagnosis still lacks a unified quantitative indicator system. Voice-feature analysis in listening-smelling diagnosis remains in the exploratory stage, and correlation models between voiceprints and syndromes are not yet mature. Information collection for inquiry-based diagnosis depends on standardized structured inquiry procedures. Although sensor precision for pulse diagnosis has achieved certain progress, there is still a gap before fully reproducing TCM practitioners' finger-sensation judgment. In constructing TCM diagnostic syndrome-differentiation models, converting the highly subjective and experience-dependent cognitive activity of "treatment based on syndrome differentiation" into computable and interpretable algorithmic logic itself represents a core research challenge in complex-systems engineering [17].

The precise execution performance of intelligent technologies still requires continuous improvement. Although robotic arms can realize accurate acupoint positioning and simulation of basic manipulations at present, technical blind-spots remain for complex operations, individualized adaptation and multi-task collaboration. Meanwhile, issues including heterogeneous multi-source data and insufficient equipment interoperability in system integration also raise the engineering difficulty of system-level optimization.

4.2 Challenges at Data and Platform Level

High-quality and large-scale datasets are the core driving factors for the intelligent transformation of TCM diagnosis and treatment. Nevertheless, TCM diagnosis-treatment data are characterized by high dimensionality, strong correlation and multi-modality, covering diverse data formats such as tongue images, pulse waveforms, inquiry texts and medical imaging data. At present, inconsistent data-collection standards, uneven quality of data annotation and imperfect data-privacy-protection mechanisms severely hinder the construction of high-quality datasets.

Data silos are still widespread in TCM diagnosis-treatment practice. Data barriers among hospitals, communities, elderly-care institutions and enterprise platforms are hard to break down. Such fragmentation not only prevents cross-institutional data sharing and collaborative utilization, but also limits the construction and in-depth analytical capacity of national-level big-data platforms for TCM diagnosis and treatment.

4.3 Bottlenecks in the construction talent teams

The intelligent transformation of TCM diagnosis and treatment urgently demands high-level compound talents who are proficient in TCM theories as well as modern technologies, and equipped with complex-systems-thinking capabilities. However, the existing talent-training system has obvious defects. TCM universities lay stress on traditional theories and clinical skills, without systematic training in modern disciplines including artificial intelligence, big-data analysis and robotics. By contrast, talents from engineering schools lack in-depth understanding of TCM thinking and clinical practice. This educational pattern marked by "separation of medicine and engineering" creates huge obstacles for cultivating interdisciplinary talents.

4.4 Market and Policy Barriers

Market-level obstacles for TCM diagnosis and treatment mainly include inadequate payment-guarantee mechanisms, insufficient supply of inclusive diagnosis-treatment products, and regional disparities in user acceptance. Specifically, the elderly group has limited overall payment capacity; long-term-care insurance covers a relatively narrow scope, and age-adapted diagnosis-treatment equipment has not been incorporated into the medical-insurance reimbursement system. This leads to high price sensitivity of relevant products and slow market popularization[18]. From the industrial perspective, most enterprises are small- and medium-sized with limited R&D investment capacity. Severe product homogenization and the absence of authoritative industry certification and evaluation systems have given rise to the phenomenon of "bad money driving out good money" from time to time [19].

Policy-related obstacles are reflected in fragmented top-level design, difficulties in cross-departmental coordination, lagging standardization procedures, and insufficient financial support for national special plans and special funds. These factors jointly create barriers for industrial-chain development and become restrictive conditions holding back the intelligent transformation of TCM diagnosis and treatment.

5. Pathways for intelligent transformation of TCM diagnosis and treatment

5.1 Draft a roadmap for tackling intelligent technologies

To address existing technical bottlenecks, key R&D tasks for intelligent TCM diagnosis-treatment should be systematically arranged during the 15th Five-Year Plan period. In the perception domain, priority should be given to advancing the development of high-precision flexible sensors, multispectral-imaging technologies and natural-language-processing systems, especially to tackle sensor stability and repeatability challenges under long-term dynamic operating conditions. In the cognition domain, large-scale, multi-dimensional and multi-level TCM diagnosis-treatment knowledge graphs and large-models for syndrome-differentiation-based decision-making shall be constructed to improve model interpretability and clinical generalization performance. In the execution domain, core technologies including flexible joint control, force-sensing and adaptive regulation, and precise multi-physical-factor output should be broken through to guarantee safety and reliability of diagnosis-treatment under complex operating environments.

Meanwhile, emphasis shall be placed on promoting functional collaboration and integrated design among the perception, cognition and execution layers. Fragmented technical orientations and disorderly system-integration hierarchies should be avoided, so that the full chain from data collection to execution feedback can realize overall optimization rather than partial local optimization.

5.2 Initiate the standardization of TCM diagnosis and treatment

Benchmark internationally, a framework covering equipment performance testing, data-interface specifications, service-quality evaluation and ethical-review standards shall be systematically constructed in light of China's practical TCM diagnosis-treatment practices. The Standardization Administration of China shall take the lead, together with the Ministry of Industry and Information Technology (MIIT), health authorities, drug regulatory authorities and other relevant departments, to jointly promote the formulation of standards for intelligent TCM diagnosis-treatment equipment.

In terms of platform construction, efforts should focus on building a national-level TCM

health-care data-sharing platform that integrates perception, diagnosis, execution and health-management functions, and realizes data interconnection and collaboration among medical institutions, community elderly-care sites, households and smart devices. It is necessary to explore and establish a four-in-one closed-loop service model of "community screening – remote diagnosis – home-based therapy – data tracking", break information barriers between online-offline scenarios as well as institutional and home-based care, and achieve data-driven diagnosis-treatment services.

5.3 Cultivate a collaborative ecosystem

The successful intelligent transformation of TCM diagnosis and treatment requires multi-dimensional collaboration among governments, enterprises, universities, research institutions and application terminals. It is recommended that the Ministry of Industry and Information Technology take the lead and cooperate with departments such as the National Development and Reform Commission, the Ministry of Civil Affairs, the National Health Commission and the Ministry of Science and Technology to formulate and implement the Medium- and Long-term Development Plan for the TCM Smart Health-care Industry, clarifying key strategic directions, core-technology breakthrough tasks and industrial-support policies.

In education and research, top-tier science and engineering universities should be encouraged to establish "medicine-engineering interdisciplinary research institutes" and "joint laboratories for TCM intelligence" in cooperation with TCM universities. Interdisciplinary talents equipped with complex-systems-engineering thinking shall be jointly cultivated by TCM universities, tertiary-level hospitals (geriatrics and pain medicine departments) and community hospitals. Insurance institutions should be guided to cooperate with enterprises manufacturing intelligent TCM equipment to explore a closed-loop business model of "service as insurance, usage as guarantee", lowering usage barriers for end-users.

5.4 Build lifecycle intelligent diagnosis and treatment service system

The intelligent transformation of TCM diagnosis and treatment shall aim to deliver integrated services covering prevention, diagnosis-treatment, rehabilitation, health preservation and hospice care for the elderly, and realize the critical shift from disease-oriented treatment to health-oriented maintenance.

At the prevention point, relying on intelligent devices and system platforms, we carry out constitution identification and early health-risk screening for the elderly and formulate personalized health-management plans. The TCM philosophy of "preventing diseases before their onset" is put into concrete practice. At the diagnosis-treatment point, an intelligent auxiliary diagnosis-treatment system integrating Chinese and Western medicine should be established. Targeting the complex features of elderly patients with multiple comorbidities, AI-assisted syndrome-differentiation and decision-making systems are adopted to generate individualized multi-system balanced treatment pathways. At the rehabilitation point, intelligent TCM diagnosis-treatment devices and remote-rehabilitation-guidance systems shall be popularized to extend high-level rehabilitation services to communities and households and expand service coverage. At the health-preservation point, an intelligent care network connecting communities and households should be constructed to realize full-chain services ranging from health monitoring to assisted living, bridging the last-mile gap of smart health-care[19][20].

6. Conclusion

The intelligent transformation of TCM diagnosis and treatment concerns not only the modernization of traditional medicine, but also the wellbeing of hundreds of millions of Chinese elderly people in achieving accessible medical care in old age. From the unique perspective of systems engineering, this paper analyzes the systemic challenges that must be addressed for the intelligent development of TCM diagnosis and treatment. The core conclusions are presented as follows:

First, the intelligent transformation of TCM diagnosis and treatment must start from the contrast between "holism" and "reductionism", "syndrome-differentiation" and "symptomatic treatment" in TCM theories and traditional engineering thinking. A technical system covering the perception layer, cognition layer, execution layer and health-care ecosystem should be constructed. Genuine complex-systems-engineering solutions can be formed through in-depth collaboration and continuous evolution across multiple layers [21].

Second, intertwined bottlenecks in technology, data, talent and policy create obstacles for the intelligent transformation of TCM diagnosis and treatment. Multi-dimensional systematic efforts in technology R&D, standards construction, talent cultivation and policy coordination are required to break structural constraints among different elements and achieve the leap from "single-point innovation" to "system-oriented innovation".

Third, for medium- and long-term development, it is necessary to formulate scientific and forward-looking industrial-planning roadmaps, build an innovation ecosystem featuring unified standards, data interoperability, platform collaboration and in-depth multidisciplinary integration, accelerate the application deployment and competitiveness cultivation of intelligent TCM diagnosis-treatment, and develop a Chinese-style solution that leads global smart health and elderly-care industry.

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