



Contents lists available at ScienceDirect

Integrative Medicine Research

journal homepage: www.elsevier.com/locate/imr

Education Article

Traditional, complementary, and integrative medicine and artificial intelligence: Novel opportunities in healthcare

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ARTICLE INFO

Keywords:

Artificial intelligence
Complementary and integrative medicine
Novel opportunities in healthcare
Traditional medicine

ABSTRACT

The convergence of traditional, complementary, and integrative medicine (TCIM) with artificial intelligence (AI) is a promising frontier in healthcare. TCIM is a patient-centric approach that combines conventional medicine with complementary therapies, emphasizing holistic well-being. AI can revolutionize healthcare through data-driven decision-making and personalized treatment plans. This article explores how AI technologies can complement and enhance TCIM, aligning with the shared objectives of researchers from both fields in improving patient outcomes, enhancing care quality, and promoting holistic wellness. This integration of TCIM and AI introduces exciting opportunities but also noteworthy challenges. AI may augment TCIM by assisting in early disease detection, providing personalized treatment plans, predicting health trends, and enhancing patient engagement. Challenges at the intersection of AI and TCIM include data privacy and security, regulatory complexities, maintaining the human touch in patient-provider relationships, and mitigating bias in AI algorithms. Patients' trust, informed consent, and legal accountability are all essential considerations. Future directions in AI-enhanced TCIM include advanced personalized medicine, understanding the efficacy of herbal remedies, and studying patient-provider interactions. Research on bias mitigation, patient acceptance, and trust in AI-driven TCIM healthcare is crucial. In this article, we outlined that the merging of TCIM and AI holds great promise in enhancing healthcare delivery, personalizing treatment plans, preventive care, and patient engagement. Addressing challenges and fostering collaboration between AI experts, TCIM practitioners, and policymakers, however, is vital to harnessing the full potential of this integration.

1. Introduction

In an era characterized by rapid technological advancements and a growing emphasis on patient-centered care, the convergence of traditional, complementary, and integrative medicine (TCIM) and artificial intelligence (AI) stands as a promising frontier in healthcare.¹ TCIM is a holistic approach to healthcare that combines conventional medical practices with complementary therapies and modalities. It places a strong emphasis on treating the whole person, focusing not only on physical health but also considering mental, emotional, and spiritual well-being.^{2,3} AI, on the other hand, has garnered significant attention in recent years for its potential to revolutionize healthcare through data-driven decision-making, predictive analytics, and personalized treatment plans.^{4,5}

This article aims to explore the intersection of TCIM and AI, shedding light on how the integration of AI technologies can enhance and complement the principles of TCIM. While both fields have distinct origins and philosophies, researchers of both fields share common objectives, such as improving patient outcomes, enhancing the quality of care, and promoting wellness. However, the potential benefits and challenges of merging these seemingly disparate approaches warrant careful consideration.

2. AI and TCIM

2.1. Brief overview of TCIM

Defining TCIM has proven to be a multifaceted and evolving task. The World Health Organization (WHO) defines “traditional medicine” as

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<https://doi.org/10.1016/j.imr.2024.101024>

Received 8 November 2023; Received in revised form 2 February 2024; Accepted 7 February 2024

Available online 9 February 2024

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“...the sum total of the knowledge, skill, and practices based on the theories, beliefs, and experiences indigenous to different cultures, whether explicable or not, used in the maintenance of health as well as in the prevention, diagnosis, improvement or treatment of physical and mental illness”.⁶ According to the US National Center for Complementary and Integrative Health (NCCIH), “complementary” medicine refers to a non-mainstream approach used alongside conventional medicine.² They further characterize “integrative health” as the convergence of conventional and complementary approaches in a coordinated manner.² In the cases of “alternative”, “complementary” and “integrative”, these terms suggest an association with conventional medicine, potentially limiting the classification of therapies lacking a defined or non-existent connection to conventional healthcare.³

In many regards, TCIM is a patient-centric approach that seeks to address not only the symptoms of illness but also the underlying causes, taking into account the physical, emotional, social, and spiritual aspects of health.⁷ It integrates conventional medical practices with a wide range of complementary therapies, including acupuncture, herbal medicine, mindfulness meditation, yoga, and nutrition.⁸ This approach acknowledges the limitations of a purely disease-focused model of healthcare and embraces a more holistic view of wellness.²

TCIM has gained recognition and acceptance in recent years, with an increasing number of medical institutions and healthcare professionals incorporating complementary therapies into their practice.⁹ Patients, too, are showing a growing interest in integrative approaches, seeking alternatives to pharmaceutical interventions and surgical procedures. As the demand for TCIM continues to rise,¹⁰ it is crucial to explore how AI can complement and enhance this approach to healthcare.

2.2. Introduction to AI in healthcare

AI, a branch of computer science, involves the development of algorithms and computer systems that can perform tasks typically requiring human intelligence, such as problem-solving, decision-making, and pattern recognition.^{11,12} In healthcare, AI has emerged as a powerful tool with the potential to transform various aspects of the industry, from diagnostics and treatment planning to patient engagement and administrative tasks.¹³⁻¹⁵

AI technologies, including machine learning and natural language processing, have already demonstrated their utility in healthcare through applications like medical image analysis, predictive modeling, and chatbots for patient interactions.^{13,16} These innovations have the potential to reduce diagnostic errors, improve treatment outcomes, and enhance the overall patient experience.^{13,16} However, as AI continues to advance, it is essential to explore its role in supporting the principles of TCIM, which places a strong emphasis on individualized care and a holistic view of health.

2.3. Understanding AI's capabilities as a transformative tool in TCIM

AI is emerging as a transformative tool within the realm of TCIM, offering a new horizon for enhancing patient care, personalization, and holistic well-being.^{17,18} TCIM practitioners exist at a unique point in history where they will have to decide about how to interact with AI. Understandably, some TCIM practitioners may have concerns about redundancy and jobs security in this era of increasingly AI-driven healthcare. Other TCIM practitioners may see opportunity and promise in AI technologies, which have the potential improve their practice and positively transform their field. To appreciate its full potential within this context, it is essential to understand AI's capabilities.

2.4. Current AI applications in TCIM

As of early 2024, AI is already making substantial inroads into the TCIM field, fostering new approaches to patient care, holistic well-being, and treatment modalities:

Diagnostic augmentation: AI-powered diagnostic tools can analyze patient data, including medical records and imaging results, to assist in early disease detection and differential diagnoses. TCIM practitioners can benefit from these tools to support their assessments and develop a more comprehensive view of their patients' health.¹⁹⁻²¹

Personalized treatment plans: TCIM emphasizes individualization in patient care. AI can analyze a patient's comprehensive health profile to recommend treatments that combine conventional medical approaches with complementary therapies, tailored to the patient's preferences and needs. This personalized approach aligns seamlessly with the principles of TCIM.^{21,22}

Predictive analytics for preventive medicine: A central tenet of TCIM is preventive care. AI excels in identifying health trends and predicting disease risks, enabling proactive interventions to prevent illnesses. By providing insights into patients' unique health trajectories, AI further supports the preventive focus of TCIM.²³⁻²⁵

Patient engagement and education: TCIM encourages patients to take an active role in their health. AI-powered virtual health assistants can enhance patient engagement by providing information, answering questions, and offering guidance on integrative therapies and practices. They can also tailor educational materials to patients' specific treatment plans and personal health goals.^{13,26}

2.5. Case examples: real-world applications

The relationship between AI and TCIM becomes apparent when we explore real-world case studies and examples that demonstrate practical applications. Below are provided some example citations for each item, however, one can imagine that AI can play a potential role across a myriad of TCIM therapies and/or disease/conditions.

Imaging: In acupuncture, ultrasound is used to view deep structures. AI could be employed to distinguish in real-time whether these structures are muscles, nerves, tendons, or blood vessels.²⁷

Diagnosis: In traditional Chinese medicine (TCM), there are often discrepancies in the accuracy of tongue diagnosis (tongue inspection) and pulse diagnosis. Utilizing AI in TCM-specific diagnostic procedures could enhance the precision of these diagnoses.²⁸

Treatment plans: A clinical decision supporting system (CDSS) could be applied in TCIM to suggest appropriate treatment prescriptions for new patients using previously collected data on symptoms, genetic traits, and health profiles of other patients, particularly in the context of herbal medicine. Particularly noteworthy is the shift from focusing solely on symptoms to incorporating genetic aspects into treatment plans. This personalized approach in TCIM could potentially lead to an increase in treatment efficacy in the future. Furthermore, the CDSS could also facilitate decisions regarding whether a patient's symptoms or illness are better managed through TCIM or if conventional medicine would be a more appropriate treatment approach.^{17,29}

AI-driven herbal medicine recommendations: TCIM often integrates herbal remedies, emphasizing holistic well-being. In AI-driven healthcare, AI plays a key role in tailoring herbal treatments to individual needs. Beyond analyzing health profiles and genetic data, AI focuses on specific symptoms, ensuring a more personalized recommendation. Additionally, traditional diagnostic methods like pulse and tongue diagnosis are integrated, providing unique insights into an individual's constitution. This collaborative approach bridges traditional practices with modern technology, enabling healthcare providers to offer tailored herbal treatments that address both symptoms and constitutional characteristics. This integration marks a significant step in advancing precision in TCIM, blending traditional wisdom with AI technology for more effective and individualized therapeutic interventions.³⁰⁻³²

Predictive modeling for chronic disease management: TCIM practitioners often focus on managing chronic diseases through lifestyle modifications. AI can predict disease progression and identify early intervention points for patients with chronic conditions. TCIM practitioners can

then tailor their care plans to target the specific needs of each patient, enhancing their overall quality of life.^{33–36}

AI-powered integrative cancer treatment: Cancer care within TCIM may incorporate approaches like acupuncture and dietary therapy alongside conventional treatments. AI can assess a cancer patient's response to various integrative therapies, helping healthcare providers tailor treatment regimens to optimize the patient's overall well-being and improve quality of life.^{37–39}

Virtual health assistants for integrative care: AI-driven virtual health assistants can guide patients in TCIM practices, such as mindfulness meditation, yoga, or dietary modifications. They provide continuous support and education, fostering a deeper connection between patients and their health. This aligns with TCIM's emphasis on patient engagement and empowerment.^{14,40,41}

3. Challenges that exist at the intersection of AI and TCIM

The integration of AI into TCIM represents unprecedented opportunity, but it also brings forth a unique set of challenges which must be considered.⁴² We acknowledge that in this article, we describe concepts surrounding how AI can be used in TCIM from a theoretical perspective, it is also necessary to point out that limitations will exist in real-world clinical practice and a need will exist to consider ways to overcome them. For example, at present and due to the nature of empirical studies, many clinicians are highly skeptical about whether AI algorithms can yet provide appropriate answers. This, among other challenges, are intertwined with the principles of TCIM and it would not make sense to omit from this article, a discussion that addresses them thoughtfully.

3.1. Scarcity of data and standardization

One of the greatest obstacles in AI-driven research within the TCIM field is the scarcity of data. To accumulate data, it is essential to standardize terminology. However, compared to conventional medicine, the standardization of terms in TCIM is lagging.⁸ This delay hampers the development and distribution of standardized electronic medical records (EMRs).^{43,44} For AI-utilized practices and research, establishing the basic infrastructure for data collection, including standardized terminology and EMRs, must be prioritized.⁴⁵ One of the largest barriers to establishing this is the fact that TCIM encompasses a large group of unrelated therapies originating from a wide range of geographic regions and schools of thought, and to date there is still no standardized method that can account for all aspects of TCIM use (e.g., diagnosis, treatment, etc.) across all regions internationally.⁸

3.2. Data privacy and security: safeguarding sensitive healthcare information

In a digital age characterized by the extensive use of AI, it becomes imperative to safeguard sensitive healthcare information in the context of TCIM:

Holistic patient data: TCIM gathers comprehensive patient data, including medical records, lifestyle information, genetic profiles, and emotional health. Protecting this holistic dataset from data breaches and unauthorised access is paramount. AI-driven healthcare systems must adhere to robust data privacy and security measures to ensure patient trust remains intact.^{46,47}

Patient trust: Trust is the foundation of the patient-provider relationship in TCIM. When AI is introduced into this relationship, patients may have concerns about data privacy and security.^{46,48,49} It is the responsibility of TCIM practitioners to communicate the measures in place to protect patient data, promoting a sense of security and trust.

Informed consent: Patients should have the opportunity to provide informed consent for AI-driven healthcare. This aligns with the patient-centered approach of TCIM, where patient preferences and choices are respected.^{50,51} While we acknowledge that informed consent policies

vary by country, it is important that researchers follow the relevant regulations and laws in their respective jurisdictions.

3.3. Regulatory and legal aspects: navigating complex healthcare regulations

TCIM commonly incorporates diverse therapies and practices. When AI is integrated into this multifaceted healthcare approach, it introduces complexities in navigating healthcare regulations:

Data privacy laws: Regulations like the Health Insurance Portability and Accountability Act (HIPAA) in the United States and the General Data Protection Regulation (GDPR) in Europe govern patient data protection.^{46,52,53} Healthcare providers must adhere to these stringent laws when using AI in patient care.

Legal accountability: Determining responsibility in cases of AI-related errors or adverse outcomes can be complex. The legal framework should provide clear guidelines for addressing such situations.^{42,54} TCIM practitioners need to be well-versed in these legal aspects to ensure ethical and legal healthcare practices.

3.4. The human touch: balancing AI with compassionate care in patient-provider relationships

TCIM is characterized by its emphasis on the human touch in healthcare. The introduction of AI challenges this balance. It will be of importance that TCIM practitioners play a pivotal role in augmenting AI rather than being diminished to mere facilitators of patients' safe use and expectations of AI in the evolving healthcare landscape. As opposed to AI overshadowing the unique skills and knowledge of TCIM practitioners, it should instead be the case that practitioners leverage the inherent capabilities of AI to free up their time for other responsibilities:

Maintaining empathy: TCIM practitioners pride themselves on their ability to offer compassionate, empathetic care. While AI can enhance efficiency and provide data-driven insights, it should not overshadow the importance of the human interaction. The utilization of AI may be able to significantly reduce the time spent on diagnosing patients and establishing treatment plans. This time saved can be redirected towards strengthening the TCIM practitioner-patient relationship, allowing for more time to be devoted to building these connections and enhancing empathy. TCIM practitioners must find a way to ensure that the patient-provider relationship remains compassionate, empathetic, and deeply therapeutic.^{55–57}

Patient expectations: Patients seeking TCIM often do so for its holistic and patient-centered approach. TCIM practitioners must communicate clearly with patients about the role of AI in their care and set realistic expectations to ensure a harmonious blend of technology and human interaction.^{58,59}

3.5. Bias and fairness: mitigating bias and ensuring equitable access

TCIM champions fairness and equal access to healthcare. The integration of AI can introduce bias challenges:

Bias in AI algorithms: AI algorithms can inherit biases present in training data, which may lead to disparities in healthcare outcomes. TCIM practitioners need to be diligent in evaluating AI systems for potential biases, working with data scientists and AI experts to mitigate and correct these biases.^{60,61}

Equitable access: TCIM seeks to provide healthcare that is accessible and beneficial to all. AI recommendations should be fair and not exacerbate healthcare disparities. TCIM practitioners should critically assess AI-driven insights and recommendations to ensure that they are accessible and beneficial to all patient populations.^{62–64}

4. Future directions

The future of TCIM enriched by AI promises untapped opportunities and innovative collaborations. This section explores the potential

growth areas and research frontiers, highlighting the importance of collaborative efforts to unlock the full potential of this harmonious integration.

4.1. Potential growth areas and untapped opportunities

Advanced personalized medicine: TCIM combined with AI has the potential to usher in a new era of truly individualized care. AI can analyze genetics, environmental factors, and patient preferences to craft personalized treatment plans, taking into account the patient's entire well-being. Two examples of this include: (1) the use of AI algorithms to analyze genetic data and historical records of herbal medicine usage (similar to that of personalized medicine⁶⁵) to determine the most effective herbal treatments for individual patients, and (2) the application of AI to monitor a patient's physiological responses during meditation and adjusting the meditation guidance in real-time to optimize its effectiveness for the individual.⁶⁶

TCIM therapy advancements: AI can assist in understanding the mechanisms behind various TCIMs, shedding light on their efficacy and safety. This knowledge can further the integration of TCIM therapies with conventional medicine for more comprehensive and evidence-based care. One example can include the use of AI to analyze data from acupuncture treatments, shedding light on the specific pathways through which acupuncture exerts its therapeutic effects, and keeping a record of the clinical effectiveness of treatments.⁶⁷ Another example, includes the use of AI algorithms to analyze extensive databases of herbal medicine information, providing insights into potential contraindications and side effects, thus contributing to safer and more evidence-based herbal medicine practice.¹⁷

Enhanced preventive care: TCIM's preventive focus aligns with AI's predictive capabilities. AI-driven models can provide early disease warnings and suggest lifestyle modifications or interventions to stave off illness, offering a proactive approach to well-being. One example of this can include the use of AI to analyze user data, including heart rate variability and stress levels, to provide personalized recommendations for improving lifestyle and reducing the risk of chronic diseases.⁶⁸

4.2. Research frontiers: warranted further exploration and development

Research that may be specifically of value to conduct in the near future which exists at the intersection of AI and TCIM can include, though is certainly not limited to, the following:

Patient-provider interaction studies: Investigating how the introduction of AI impacts the patient-provider relationship in TCIM is crucial. Research that seeks to identify how compassion is discussed in relation to AI technologies in healthcare and explore gaps in current knowledge can help identify the optimal balance between AI-driven insights and compassionate care.⁶⁹

Bias mitigation research: Ongoing research is necessary to identify and mitigate biases in AI algorithms used within healthcare, TCIM being no exception. This ensures fair and equitable healthcare outcomes.^{70,71}

Patient acceptance and trust studies: Research can delve into how patients perceive and accept AI in their care, with a focus on factors that enhance or hinder trust. Understanding patient perspectives can guide the ethical use of AI in healthcare.⁷²

5. Conclusions

The intersection of TCIM and AI constitutes novel, uncharted opportunities in healthcare, poised to redefine patient care and treatment paradigms. Current research would indicate that TCIM's holistic principles, emphasizing personalized and patient-centered care has already begun to converge with AI capabilities. This amalgamation holds great promise in enhancing healthcare delivery, fostering personalized treatment plans, preventive interventions, and patient engagement. However, it also introduces a suite of formidable challenges, regarding data

privacy, regulatory complexities, preserving the human dimension in healthcare, and mitigating biases within AI algorithms. Collaboration between AI experts, TCIM practitioners, and policymakers emerges as a vital necessity in addressing these challenges and harnessing the full potential of these opportunities. It can be anticipated that future work at this intersection will revolve around topics such as advanced TCIM therapy advancements (e.g., AI-enhanced herbal medicine), patient-provider AI-interaction studies, AI bias mitigation, and the critical exploration of patient acceptance and trust in AI-driven TCIM healthcare.

CRedit authorship contribution statement

Jeremy Y. Ng: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Holger Cramer:** Writing – review & editing. **Myeong Soo Lee:** Writing – review & editing. **David Moher:** Writing – review & editing.

Declaration of competing interest

This article was invited but it was externally peer reviewed. The authors declare that they have no competing interests.

Funding

None.

Ethical statement

This review involved a search and review of literature. Therefore, it did not require ethical approval.

Data availability

All relevant data are included in this manuscript.

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