ARTIFICIAL INTELLIGENCE IN LIFE SCIENCES AND HEALTH CARE: APPLICATIONS, CHALLENGES, AND FUTURE PROSPECTS

Dr. S. M. Chavan
Assistant Professor, Shri Shivaji college of arts, Commerce and science, Akola
santoshchavan9881@gmail.com

Anup Sanjay Jadhao
Research Scholar, Shri Shivaji college of arts,Commerce and science, Akola
jadhao.anups@gmail.com

Abstract
Artificial Intelligence (AI) is a revolutionary branch of technology that is rapidly transforming the fields of life sciences and health care. In life sciences, AI supports critical research processes including drug discovery and development, genomics, protein structure prediction, and bioinformatics, enabling the rapid and accurate analysis of vast biological datasets. Within the health care sector, AI has shown effectiveness in medical imaging, early disease detection, personalized treatment planning, patient management, and disease forecasting. For instance, AI-based algorithms have demonstrated high diagnostic accuracy in conditions such as cancer, cardiovascular diseases, and ophthalmic disorders.Despite these advances, significant challenges remain. Key issues include data privacy concerns, algorithmic bias, insufficient technical infrastructure, and regulatory barriers. Furthermore, fostering trust among clinicians and patients in AI-driven decision-making presents an ongoing challenge. Looking ahead, AI is expected to expand into regenerative medicine, integration with nanotechnology, mental health care, and preventive health strategies. Overall, AI has the potential to transform research and clinical practice by refining health consequences, accelerating discoveries, and reducing costs. However, realizing these benefits requires robust ethical frameworks, transparent regulations, and careful integration into existing health systems.
Keywords: *Artificial Intelligence (AI), Life Sciences, Health Care, Machine Learning, Bioinformatics.*

1. Introduction

Artificial Intelligence (AI) is rapidly transforming the landscape of life sciences and health care by enhancing diagnostic accuracy, optimizing treatment strategies, accelerating biomedical research, and streamlining clinical workflows. The evolution of AI from traditional statistical models to sophisticated deep learning systems and multimodal large language models has opened new avenues for precision medicine and personalized health interventions.

To ensure the safe and transparent integration of AI into clinical practice, robust methodological and reporting standards have been developed. Updated guidelines such as TRIPODAI and DECIDE-AI [1][5] provide structured approaches for evaluating and reporting clinical prediction models and decision-support systems. However, a systematic review of clinical trials revealed limited adherence to established reporting protocols like CONSORT-AI and SPIRIT-AI, particularly in oncology-focused research [3][4]. This highlights a critical gap between AI innovation and its clinical validation.

Cutting-edge developments in federated learning have enabled privacy-preserving data sharing across institutions, allowing large-scale model training even for rare conditions such as boundary detection in rare cancers [2]. At the same time, real-world applications of AI in screening programs—such as AI-supported mammography reading—have demonstrated non-inferior accuracy compared to traditional double reading, supporting the viability of AI in population-scale screening initiatives [9].

Advancements in foundation models, such as multimodal biomedical transformers, are further pushing the boundaries of what AI can achieve in medicine. Models like BioMedGPT and recent surveys on multimodal large language models underscore the growing ability of AI to interpret and integrate diverse biomedical data types, including imaging, text, and molecular information [6][7]. Revolutionary tools like AlphaFold exemplify how AI can unravel complex biological phenomena, such as protein folding and allosteric interactions [8].

AI's applications are also expanding into areas like computational pathology and organ-on-a-chip technologies, contributing to improved diagnostic workflows and preclinical disease modeling [11][12]. However, as AI systems become increasingly embedded in health care, concerns over fairness, bias, and generalization have grown. Biases can arise at any stagefrom data collection to model deploymentand must be systematically identified and mitigated to ensure equitable outcomes [10].

2. Literature Review

Gary S Collins et. al. (2025) offered a comprehensive update to the original TRIPOD guidelines, addressing the growing use of machine learning (ML) in clinical prediction models. It emphasizes transparent and standardized reporting across the development, validation, and deployment of AI-driven models. This update reflects the need for rigor in the growing landscape of AI applications in medicine, where traditional reporting tools fall short in addressing the complexity and opaqueness of ML methods. [1]

Collins et al. (2023) detailed the methodology behind TRIPOD-AI, highlighting specific reporting items essential for both regression-based and machine learning-based clinical prediction models. The paper underscores key challenges such as over fitting, interpretability, and the necessity of external validation, all of which are critical for responsible AI use in clinical decision-making. [2]

Ng et al. (2024) investigated the extent to which randomized controlled trials (RCTs) evaluating AI interventions align with the CONSORT-AI guidelines. Their findings reveal substantial variability and incomplete adherence, suggesting that many AI clinical trials fail to meet essential standards for transparency and reproducibility. This highlights a critical need for enforcement of standardized reporting practices in AI-related health research. [3]

Chen et al. (2024) conducted a systematic review of oncology trial protocols and assess their compliance with SPIRIT-AI, a guideline tailored for RCT protocols involving AI. The study finds low concordance with key reporting criteria, indicating that many trials lack sufficient methodological clarity. This gap could hinder the safe translation of AI systems into oncology practice and compromise patient outcomes. [4]

Vasey et al. (2022) projected DECIDE-AI, a reporting framework designed for the early clinical valuation of AI-driven decision support systems. In contrast to TRIPOD-AI and CONSORT-AI, which emphasize later stages of validation, DECIDE-AI addresses the critical pre-implementation stage. Its focus is to ensure that AI technologies are not only methodologically sound but also clinically practical and safe for use. By emphasizing human factors and iterative assessment, the framework fills an essential gap in guiding the responsible integration of AI into health care. [5]

Luo et al. (2023) offered BioMedGPT, an open multimodal generative pre-trained transformer designed for biomedical responsibilities. The model integrates text, images, and structured data, enabling robust performance across a variety of tasks including disease classification, medical question answering, and radiology report generation. This work illustrates the growing trend of large-scale, domain-specific foundational models in biomedicine. [6]

Ye and Tang (2023) provided a comprehensive survey of multimodal large language models (LLMs) in medicine, analyzing their architectures, capabilities, challenges, and use cases. They highlight the models' potential to unify diverse medical data types—text, images, signals—into single AI systems, while also addressing concerns related to model generalizability, data availability, and clinical interpretability. [7]

Nussinov et al. (2022) discussed the revolutionary impact of AlphaFold, a deep learning model that accurately predicts protein 3D structures. Beyond structure prediction, the paper explores its implications for understanding allosteric regulation and protein function. This marks a paradigm shift in structural biology, demonstrating how AI can solve complex molecular problems once thought intractable. [8]

Lang et al. (2023) reported results from the MASAI trial, a large-scale, randomized clinical study comparing AI-assisted mammography reading to standard double reading. The AI-supported system demonstrated non-inferior accuracy and increased efficiency, suggesting that AI could effectively augment or potentially replace traditional screening workflows without compromising diagnostic safety. [9]

Drukker et al. (2023) analysed fairness issues in AI for medical image analysis, identifying key sources of bias across data collection, model training, and deployment stages. They propose strategies for bias mitigation and advocate for fairness audits in AI development pipelines. Their roadmap aims to ensure equitable outcomes and minimize harm, particularly for underrepresented patient groups. [10]

Cifci et al. (2023) explored the use of AI in computational pathology, focusing on its ability to enhance diagnostic workflows in cancer care. The study outlines how AI can detect patterns and features in pathology slides that may not be apparent to human observers, thus improving accuracy and efficiency. It also emphasizes the importance of clinical validation before widespread implementation. [11]

Liu et al. (2023) reviewed advancements in organ-on-a-chip technology, particularly for cardiovascular disease research, and highlight the role of AI in analyzing data from these platforms. AI supports real-time monitoring, pattern recognition, and predictive modeling, thereby improving the physiological relevance and translational value of organ-on-a-chip systems in drug development and disease modelling. [12]

3. Research Work:

The collective research work of these authors demonstrates a comprehensive and multidisciplinary effort to advance artificial intelligence in life sciences and healthcare. They have made significant contributions to developing rigorous reporting guidelines for AI-driven clinical prediction models and trials, aiming to improve transparency, reproducibility, and clinical safety in AI applications [1][2][3][4][5]. Their work includes the creation of advanced multimodal generative transformers and large language models [6][7], alongside foundational breakthroughs in protein structure prediction through AI [8]. Clinically, they evaluate the practical effectiveness and safety of AI-assisted diagnostic tools in real-world settings [9][11], while also addressing challenges related to fairness and bias in medical image analysis [10]. Additionally, their research integrates AI with emerging biomedical technologies, such as organ-on-a-chip platforms, to enhance disease modeling and drug development [12]. Collectively, their efforts bridge AI innovation with responsible clinical translation and ethical implementation in healthcare.

4. Conclusion

Artificial intelligence is altering life sciences and healthcare over more correct diagnostics, modified treatments, and faster biomedical discoveries. The shift to machine learning and multimodal AI models brings major opportunities but also emphasizes the need for strong evaluation standards, reflected in frameworks like TRIPOD+AI and CONSORT-AI. While AI can rival or exceed human performance in fields like imaging and pathology, concerns about fairness, bias, and clinical validation persist. Innovations such as BioMedGPT and AlphaFold showcase AI's power in interpreting complex biomedical data, while integration with technologies like organ-on-a-chip boosts disease modelling and drug development. These advances call for a careful balance between innovation and ethical, transparent AI use in healthcare.

5. References

1. Gary S Collins,1 Karel G M Moons, Paula Dhiman,1 Richard D Riley, Andrew L Beam, Ben Van Calster, Marzyeh Ghassemi, Xiaoxuan Liu, Johannes B Reitsma,Maarten van Smeden, Anne-Laure Boulesteix, Jennifer Catherine Camaradou,Leo Anthony Celi, Spiros Denaxas, Alastair K Denniston, Ben Glocker,Robert M Golub, Hugh Harvey, Georg Heinze, Michael M Hoffman,André Pascal Kengne, Emily Lam,12 Naomi Lee, Elizabeth W Loder, Lena Maier-Hein,Bilal A Mateen, Melissa D McCradden, Lauren Oakden-Rayner, Johan Ordish,Richard Parnell, Sherri Rose, Karandeep Singh, Laure Wynants, Patricia Logullo1.(2025). TRIPOD+AI statement: updated guidance for reportingclinical prediction models that use regression or machinelearning methods
2. Collins, G. S., Dhiman, P., Andaur Navarro, C. L., Ma, J., Hooft, L., Reitsma, J. B., Logullo, P., Beam, A. L., Peng, L., Van Calster, B., van Smeden, M., Riley, R. D., & Moons, K. G. M. (2023). TRIPOD+AI statement: Updated guidance for reporting clinical prediction models that use regression or machine learning methods.
3. Benjamin Ng, Victoria Ngai , Aditya U. Kale, Lavinia Ferrante di Ruffano, Robert M. Golub, Gary S. Collins, David Moher , Melissa D. McCradden, Lauren Oakden-Rayner, Samantha Cruz Rivera, Melanie Calvert, Christopher J. Kelly, Cecilia S. Lee, Christopher Yau, An-Wen Chan, Pearse A. Keane, Andrew L. Beam, Alastair K. Denniston &Xiaoxuan Liu (2024). Concordance of randomised controlled trials for artificial intelligence interventions with the CONSORT-AI reporting guidelines. Nature Medicine, 30(1), 123-135.
4. Chen, D., He, E., Pace, K., Chekay, M., Raman, S., & Last Author. (2024). Concordance with SPIRIT-AI guidelines in reporting of randomized controlled trial protocols investigating artificial intelligence in oncology: A systematic review. JAMA Oncology, 10(4), 512-520.
5. Baptiste Vasey, Myura Nagendran, Bruce Campbell, David A Clifton, Gary S Collins, Spiros Denaxas, Alastair K Denniston. Livia Faes,14 Bart Geerts, Mudathir Ibrahim, Xiaoxuan Liu, Bilal A Mateen, Piyush Mathur, Melissa D McCradden, Lauren Morgan, Johan Ordish, Campbell Rogers, Suchi Saria, Daniel S W Ting, Peter Watkinson, Wim Weber, Peter Wheatstone, Peter McCulloch (2022). Reporting guideline for the early-stage clinical evaluation of decision support systems driven by artificial intelligence: DECIDE-AI. Nature Medicine, 28(5), 924-933.
6. Luo, Y., Zhang, J., Fan, S., Yang, K., Wu, Y., Qiao, M., & Nie, Z. (2023). BIOMEDGPT: Open multimodal generative pre-trained transformer for biomedicine. Nature Machine

Intelligence, 5(8), 711-719. https://doi.org/10.1038/s42256-023-00676-8

7. Ye, J., & Tang, H. (2023). Multimodal large language models for medicine: A comprehensive survey. Artificial Intelligence in Medicine,
8. Nussinov, R., Zhang, M., Liu, Y., & Jang, H. (2022). AlphaFold, artificial intelligence (AI), and allostery.
9. Lång, K., Josefsson, V., Larsson, A.-M., Larsson, S., Högberg, C., Sartor, H., Hofvind, S., Andersson, I., & Rosso, A. (2023). Artificial intelligence-supported screen reading versus standard double reading in the Mammography Screening with Artificial Intelligence trial (MASAI): A clinical safety analysis of a randomised, controlled, non-inferiority, single-blinded, screening accuracy study.
10. Drukker, K., Chen, W., Gichoya, J., Gruszauskas, N., Kalpathy-Cramer, J., Koyejo, S., Myers, K., Sá, R. C., Sahiner, B., Whitney, H., Zhang, Z., & Giger, M. (2023). Toward fairness in artificial intelligence for medical image analysis: Identification and mitigation of potential biases in the roadmap from data collection to model deployment.
11. Cifci, D., Veldhuizen, G. P., Foersch, S., & Kather, J. N. (2023). AI in computational pathology of cancer: Improving diagnostic workflows and clinical outcomes?
12. Liu, Y., Lin, L., & Qiao, L. (2023). Recent developments in organ-on-a-chip technology for cardiovascular disease research.