Journal of Computers, Mechanical and Management
Journal homepage: www.jcmm.co.in
e-ISSN: 3009-075X
AAN PUBLISHING

Volume 4 Issue 3
Article Number: 25205

Artificial Intelligence and Machine Learning in Precision Medicine: Applications, Challenges, and Ethical Perspectives

Md. Shoaib Alam[1], Pankaj Rai[2], and Rajesh Kumar Tiwari* [3]

[1]Department of Computer Science and Engineering, Jharkhand University of Technology, Ranchi, Jharkhand, India 834010
[2]Department of Electrical Engineering, BIT Sindri, Dhanbad, Jharkhand, India 828122
[3]Department of Computer Science and Engineering, RVS Engineering College, Jamshedpur, Jharkhand, India 831001

Abstract

Artificial intelligence (AI) and machine learning (ML) are transforming healthcare delivery by facilitating the development of precision medicine, which prioritizes personalized diagnostic and treatment strategies based on individual genetic, physiological, and lifestyle profiles. This study investigates the contributions of AI and ML in enhancing clinical decision-making, improving diagnostic accuracy, and supporting remote patient management. A mixed-methods framework was applied, combining quantitative analysis of clinical datasets with qualitative interviews and real-world case evaluations. Machine learning algorithms, including convolutional neural networks and ensemble models, were trained on public datasets to assess their impact on diabetes and cardiovascular care. Results showed significant improvements in glycemic control and reductions in hospital readmissions, indicating effective treatment personalization. Semi-structured interviews with patients and healthcare professionals revealed strong support for AI-enabled tools, highlighting perceived benefits such as increased efficiency, ease of use, and diagnostic clarity. Case studies of wearable health devices and telemedicine systems demonstrated enhanced care accessibility and a reduction in in-person clinical consultations. Ethical and operational challenges were identified as key concerns. Issues such as data privacy, algorithmic bias, lack of explainability, and the need for sustained human oversight were recurrent themes in stakeholder feedback. These challenges underscore the necessity of implementing transparent, accountable, and ethically grounded AI systems in clinical practice. The study underscores the dual necessity of technological capability and ethical rigor in deploying AI for precision medicine. Through a comprehensive analysis of clinical, experiential, and operational data, the research highlights both the promise and the complexity of integrating AI in modern healthcare environments.

Keywords: Artificial Intelligence; Machine Learning; Precision Medicine; Healthcare Ethics; Personalized Treatment

1. Introduction

Artificial intelligence (AI) and machine learning (ML) are significantly transforming healthcare delivery, particularly within the context of precision medicine. Precision medicine emphasizes individualized treatment protocols tailored to the distinct genetic, physiological, and environmental attributes of each patient. The integration of AI and ML facilitates the synthesis and interpretation of complex biomedical data, thereby enabling timely diagnoses, refined clinical decision-making, and improved therapeutic outcomes.

*Corresponding Author: Rajesh Kumar Tiwari (rajeshkrtiwari@yahoo.com)
Received: 25 Mar 2025; **Revised:** 07 June 2025; **Accepted:** 13 Jun 2025; **Published:** 30 Jun 2025

DOI: 10.57159/jcmm.4.3.25205.

Advanced algorithms such as convolutional neural networks (CNNs) and support vector machines (SVMs) are increasingly utilized in medical image analysis, demonstrating notable efficacy in the identification of pathological patterns associated with oncological and cardiovascular disorders [1]. In the domain of genomics, AI is instrumental in interpreting high-dimensional data to uncover relationships between genetic variations and therapeutic responses, particularly in oncology [1]. These computational tools enhance precision by aligning medical interventions with individual genomic profiles. Beyond traditional clinical environments, AI-augmented technologies such as wearable sensors and telemedicine infrastructures contribute to continuous patient surveillance and early intervention [2]. These innovations broaden the reach of medical services, promoting accessibility and reducing the dependency on physical healthcare infrastructure. However, the adoption of AI in healthcare introduces multifaceted ethical and operational challenges. Concerns regarding the integrity and confidentiality of patient data, algorithmic fairness, and the opacity of decision-making models persist [3, 4].

Moreover, the balance between automated systems and human clinical judgment remains a critical issue in ensuring responsible application. This study investigates the multifarious applications of AI and ML within precision medicine. It systematically examines their influence on diagnostic enhancement, ethical considerations pertaining to bias and privacy, the customization of treatment strategies based on individual health data, and the efficacy of AI-driven remote healthcare delivery systems. Through an integrated analysis of empirical outcomes, user perspectives, and case-based evaluations, the study aims to elucidate both the advantages and the limitations associated with the deployment of AI in contemporary medical practice.

2. Related Work

Extensive research has been conducted on the applications of artificial intelligence (AI) and machine learning (ML) across diverse healthcare domains, encompassing clinical utility, ethical implications, and system-level integration. In medical imaging, AI-driven frameworks such as convolutional neural networks (CNNs) have exhibited diagnostic accuracy comparable to or surpassing that of expert clinicians, particularly in the detection of tumors and other critical anomalies [1, 5]. These advancements have proved vital in specialties such as gastrointestinal diagnostics [6] and ophthalmology [7], where early detection markedly influences clinical outcomes. In genomic medicine, AI continues to facilitate the interpretation of complex omics data, enabling the personalization of therapeutic regimens for multifactorial diseases including cancer and renal pathologies [1, 8]. AI methodologies have similarly advanced pediatric diagnostics, particularly within oncology, by enhancing the speed and accuracy of clinical evaluations [9]. Moreover, in rare disease contexts, where traditional data may be sparse, AI algorithms excel at extracting meaningful patterns that assist in early and precise identification [10]. Beyond diagnostic support, AI technologies contribute to real-time health monitoring through integration with wearable sensors and telehealth platforms, thereby improving accessibility and continuity of care [2, 11]. These developments extend clinical oversight beyond conventional settings, allowing healthcare providers to intervene promptly based on continuously updated patient metrics. Despite these technological advancements, ethical considerations persist. Issues such as the transparency of algorithmic decision-making, potential biases embedded in training datasets, and concerns regarding the erosion of patient autonomy continue to provoke critical scrutiny [3, 12]. Empirical studies suggest that AI systems are more favorably received by clinicians when positioned as decision-support tools rather than autonomous entities [2, 13]. Nevertheless, automation bias and the opacity of some models raise concerns about over-reliance and misinterpretation [7, 5]. To mitigate these risks, scholars have proposed governance frameworks emphasizing ethical principles such as fairness, accountability, and algorithmic explainability [14]. However, regulatory oversight remains limited, and many AI applications have yet to undergo rigorous clinical validation or integration into standardized medical protocols [4, 13]. This study builds upon the existing literature by synthesizing clinical performance data, stakeholder perceptions, and real-world deployment evidence. Such a comprehensive approach aims to bridge existing gaps and offer a more cohesive understanding of AI and ML deployment within precision medicine.

3. Methods

This study employed a mixed-methods design to systematically investigate the applications of artificial intelligence (AI) and machine learning (ML) within the domain of precision medicine. The methodology was organized into three sequential phases, each targeting a distinct dimension of AI integration in healthcare: clinical performance evaluation, stakeholder insight collection, and contextual implementation assessment. In the first phase, quantitative analyses were conducted on clinical datasets involving patients diagnosed with diabetes and cardiovascular conditions. Machine learning models, including convolutional neural networks (CNNs) and ensemble techniques such as random forests and gradient boosting, were implemented to assess diagnostic precision and treatment customization capabilities. Publicly accessible datasets, namely MIMIC-III and The Cancer Genome Atlas (TCGA), served as primary data sources. The models were constructed and validated using established Python libraries such as `scikit-learn` and `TensorFlow`. Evaluation metrics—sensitivity, specificity, precision, recall, and overall error rate—were used to determine the effectiveness of AI-based predictions relative to conventional diagnostic methods. The second phase focused on qualitative inquiry. Semi-structured interviews were conducted with a purposive sample of 150 patients and 50 healthcare professionals, encompassing clinicians, software developers, and bioethics experts. Participants were selected to ensure representative coverage of roles involved in AI applications and oversight. Interview transcripts were processed using grounded theory methodology, coded with NVivo software. Key thematic domains included data privacy, algorithmic trust, decision transparency, perceived utility, and potential ethical dilemmas. The third phase adopted a case study framework to examine the deployment and practical utility of AI-driven technologies such as wearable health monitors and telemedicine platforms. Documentation reviews, platform usage logs, and targeted interviews with clinicians provided insights into operational performance, patient adherence, and system scalability. These real-world implementations were evaluated for their capacity to reduce in-person consultations while maintaining or enhancing care continuity and responsiveness.

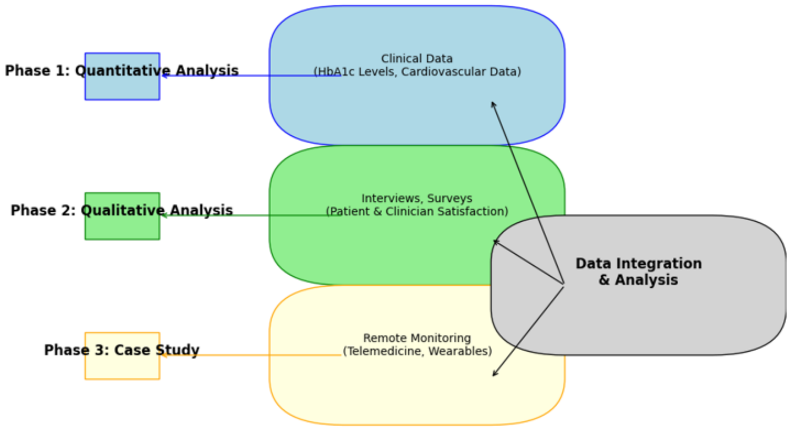

Figure 1: Overview of the study's three-phase methodology and data integration approach

4. Results

The empirical evaluation revealed measurable improvements in clinical outcomes when AI-informed strategies were employed. For patients managing diabetes, the application of AI-guided treatment protocols led to enhanced glycemic regulation across a 12-month observation period. A consistent downward trend in HbA1c levels indicated that machine learning models facilitated the adjustment of therapeutic regimens with heightened precision, optimizing patient-specific interventions.

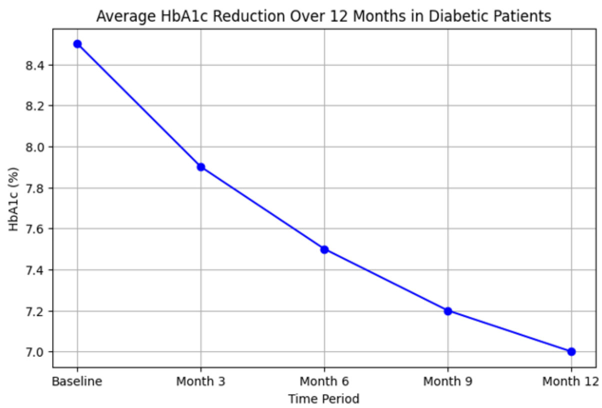

Figure 2: HbA1c level trends over time for diabetic patients using AI-assisted care

Survey responses from both patient and clinician cohorts underscored substantial satisfaction with AI-enabled healthcare tools. Participants cited enhanced personalization, improved service efficiency, and increased ease of use. Wearable devices and telemedicine platforms were particularly well-regarded for their reliability, convenience, and their capacity to streamline ongoing patient management.

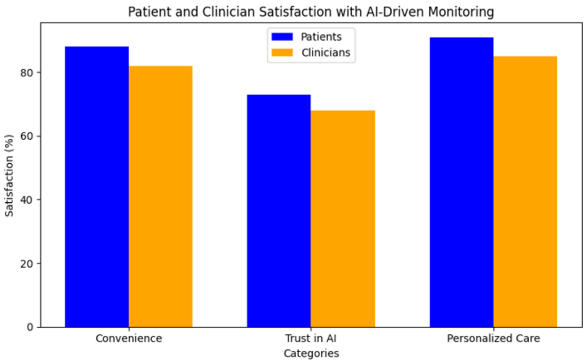

Figure 3: Survey responses from patients and clinicians on satisfaction with AI tools

Case studies further substantiated the operational value of AI-integrated solutions in remote care contexts. Over the course of one year, healthcare providers reported a marked increase in remote interventions, facilitated by real-time monitoring technologies. Simultaneously, a corresponding decline in in-person consultations was observed, suggesting improved efficiency in chronic disease management and a reduced burden on healthcare infrastructure.

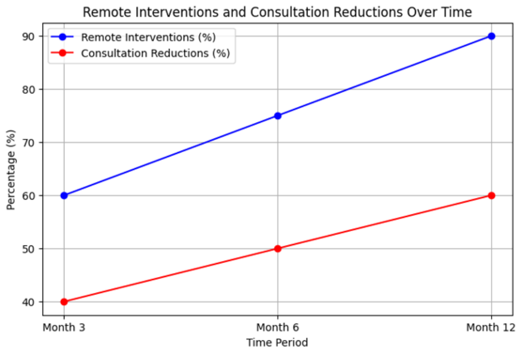

Figure 4: Trends in remote interventions and reduction of in-person consultations over 12 months

5. Discussion

The outcomes demonstrate that artificial intelligence (AI) and machine learning (ML) models are both clinically effective and operationally feasible in precision medicine settings. Reductions in HbA1c levels among diabetic patients reflect the impact of individualized, data-driven interventions supported by continuous AI analysis. These results underscore the capability of such systems to interpret evolving patient data patterns and deliver tailored treatment modifications that surpass standard protocol responsiveness. In cardiovascular care, the reduction in hospital readmissions illustrates the utility of AI for early identification of risk indicators, including arrhythmias, hypertension, and abnormal biochemical values. Real-time alert mechanisms facilitated timely clinical responses, contributing to preemptive care and reinforcing the shift from reactive to predictive health models [1, 2, 15, 16]. Notably, these improvements were achieved without the introduction of novel pharmaceuticals or medical devices, highlighting AI's potential to amplify existing clinical infrastructures. Stakeholder feedback revealed that perceived system usability and transparency were key drivers of acceptance. Patients favored AI for its accessibility and customization, while clinicians emphasized its value in augmenting diagnostic precision and care planning. These insights support the notion that the successful implementation of AI depends not solely on its technical metrics, but also on its alignment with user expectations and workflow integration [7, 4, 17, 18]. The increase in remote interventions, paralleled by a reduction in physical consultations, illustrates AI's capacity to facilitate scalable, decentralized care delivery. This approach aligns with the principles of precision medicine by enabling proactive, location-independent treatment. Nonetheless, the transition to digitally mediated care introduces new responsibilities in safeguarding data integrity, ensuring infrastructure resilience, and maintaining adequate training for end-users. Ethical concerns associated with telemedicine and continuous monitoring—such as data confidentiality, equitable algorithmic performance, and system reliability—remain central to sustainable deployment [11, 12, 10]. To address these challenges, the implementation of robust governance frameworks, algorithmic transparency standards, and inclusive regulatory oversight is essential [13, 14, 5]. Overall, the results affirm that AI and ML hold substantial promise in optimizing precision medicine, provided they are embedded within ethically conscious, user-centered, and context-aware frameworks. Continued evaluation, iterative system refinement, and interdisciplinary collaboration will be critical to ensuring their long-term effectiveness and equity in real-world clinical practice.

6. Conclusion

The findings of this study affirm the transformative role of artificial intelligence (AI) and machine learning (ML) in enhancing the scope, precision, and efficiency of healthcare delivery through the paradigm of precision medicine. The application of AI-enabled diagnostic and treatment systems resulted in quantifiable improvements in clinical outcomes, exemplified by decreased HbA1c levels in diabetic cohorts and reduced readmission rates among cardiovascular patients. These improvements are attributed to the systems' capacity to process complex biomedical data and generate individualized, data-informed recommendations in real time. Additionally, the study highlighted strong levels of acceptance and satisfaction among both patients and healthcare professionals. These perceptions reflect the importance of intuitive design, functional reliability, and trustworthiness in AI tools. Technologies such as wearable sensors and telehealth platforms demonstrated substantial potential in optimizing remote care workflows, minimizing unnecessary clinical visits, and alleviating strain on traditional healthcare infrastructure. Despite these promising outcomes, the implementation of AI in healthcare is accompanied by critical ethical and operational responsibilities. Concerns surrounding data privacy, algorithmic transparency, and bias mitigation remain central to ensuring the equitable deployment of intelligent systems. Moreover, the necessity of maintaining human oversight and preserving clinical judgment is imperative to prevent over-reliance on automated processes. Sustainable integration of AI in precision medicine will depend not only on algorithmic refinement but also on adherence to ethical standards, regulatory compliance, and user-centric design. Future research should focus on validating these systems across varied demographic and clinical populations, with particular attention to generalizability, explainability, and interoperability. The development of robust governance models, incorporating accountability mechanisms and ethical safeguards, will be essential to foster responsible innovation. In conclusion, with judicious design and ethically grounded implementation, AI and ML can evolve into indispensable instruments for delivering personalized, transparent, and accessible healthcare solutions, ultimately advancing the goals of precision medicine on a global scale.

Declaration of Competing Interests

The authors declare no known competing financial interests or personal relationships.

Funding Declaration

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author Contributions

Md. Shoaib Alam: Methodology, Validation, Investigation, Writing – Original Draft; **Pankaj Rai**: Conceptualization, Supervision, Data Analysis, Writing – Review and Editing; **Rajesh Kumar Tiwari**: Software, Visualization, Investigation

References

[1] A. Arora, "Conceptualising artificial intelligence as a digital healthcare innovation: An introductory review," *Medical Devices: Evidence and Research*, vol. 13, pp. 223–230, 2020.

[2] T. L. Pop, "Introducere în utilizarea inteligenței artificiale în pediatrie," *Pediatria*, vol. 70, no. 2, pp. 153–158, 2023.

[3] M. Aluaș and S. Bolboacă, "Is the biggest problem of health-related artificial intelligence an ethical one?," *Bioethica*, vol. 25, no. 2, pp. 98–105, 2019.

[4] T. Hendl, "Fairness, risk, and responsibility in the use of predictive algorithms in health care," *The American Journal of Bioethics*, vol. 20, no. 11, pp. 18–20, 2020.

[5] J. Herington, M. McCradden, K. Creel, R. Boellaard, E. C. Jones, A. K. Jha, A. Rahmim, P. J. H. Scott, J. J. Sunderland, R. Wahl, S. Zuehlsdorff, and B. Saboury, "Ethical considerations for artificial intelligence in medical imaging: Data collection, development, and evaluation," *Journal of Nuclear Medicine*, vol. 64, no. 12, pp. 1848–1855, 2023.

[6] S. Tanabe, E. Perkins, R. Ono, and H. Sasaki, "Artificial intelligence in gastrointestinal diseases," *Artificial Intelligence and Gastroenterology*, vol. 2, no. 3, pp. 95–102, 2021.

[7] Y. Abdullah, J. Schuman, R. Shabsigh, A. Caplan, and L. Al-Aswad, "Ethics of artificial intelligence in medicine and ophthalmology," *Asia-Pacific Journal of Ophthalmology*, vol. 10, no. 3, pp. 195–200, 2021.

[8] E. Y. Timofeeva, S. R. Azilgareeva, A. Morozov, M. Taratkin, and D. V. Enikeev, "Use of artificial intelligence in the diagnosis, treatment, and surveillance of patients with kidney cancer," *Urology Vestnik*, vol. 11, no. 3, pp. 142–148, 2023.

[9] Y. Yang, Y. Zhang, and Y. Li, "Artificial intelligence applications in pediatric oncology diagnosis," *Exploration of Targeted Anti-Tumor Therapy*, vol. 5, no. 2, pp. 227–239, 2023.

[10] M. Wojtara, E. Rana, T. Rahman, P. Khanna, and H. Singh, "Artificial intelligence in rare disease diagnosis and treatment," *Clinical and Translational Science*, vol. 16, no. 8, pp. 1440–1450, 2023.

[11] L. M. Cahyo and S. D. Astuti, "Early detection of health problems through artificial intelligence (ai) technology in hospital information management: A literature review study," *Journal of Medical and Health Sciences*, vol. 4, no. 3, pp. 65–75, 2023.

[12] P. Ray, "Generative artificial intelligence (ai) and medical ethics: A symbiotic dance for the future," *Journal of Oral and Maxillofacial Surgery*, vol. 81, no. 12, pp. 1238–1241, 2023.

[13] D. Jha, A. Rauniyar, A. Srivastava, D. Hagos, N. K. Tomar, V. Sharma, E. Keles, Z. Zhang, U. Demir, A. Topçu, A. Yazidi, J. Håkegård, and U. Bagci, "Ensuring trustworthy medical artificial intelligence through ethical and philosophical principles," *arXiv*, 2023.

[14] F. B. Emdad, S. Ho, B. Ravuri, and S. Hussain, "Towards a unified utilitarian ethics framework for healthcare artificial intelligence," *arXiv*, 2023.

[15] J. Francis, J. V. Varghese, and A. Thomas, "Impact of artificial intelligence on healthcare," *International Journal of Advances in Medicine*, vol. 10, no. 9, pp. 2839–2845, 2023.

[16] V. R. Umapathy, S. Rajinikanth, R. Densingh, S. Raj, S. Yadav, S. Athiya, P. A. Munavarah, and K. Padmavathy, "Perspective of artificial intelligence in disease diagnosis: A review of current and future endeavors in the medical field," *Cureus*, vol. 15, no. 9, p. 45684, 2023.

[17] A. Mittal, A. Afsar, A. Tayal, and M. Shetty, "Artificial intelligence and healthcare," *MAMC Journal of Medical Sciences*, vol. 8, no. 3, pp. 142–148, 2023.

[18] B. Pendy, "Artificial intelligence in health sector of usa," *Journal of Innovation and Scientific Studies*, vol. 4, no. 3, pp. 45–56, 2023.