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(Research Article)

Artificial intelligence in medical technologies: Automation of diagnostics, treatment prediction and development of innovative pharmaceutical solutions

Sergiu Metgher *

CEO/Founder - ReignCode LLC - Delaware, USA.

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Abstract

This article examines the role and potential of artificial intelligence in transforming modern medicine through three key areas: automation of diagnostic processes, treatment prediction, and the development of pharmaceutical drugs. The relevance of this topic is driven by the growing disparity between the exponential increase in medical data volume and the limited human capacity to process and interpret this information. The objective is to conduct a comprehensive analysis of innovative AI technologies and their ability to bridge this gap. The scientific community remains divided regarding the effectiveness and ethical justification of AI-driven solutions, with opinions ranging from optimistic assessments of technological potential to critical perspectives on AI's ability to address structural challenges in healthcare. The findings emphasize that AI integration does not imply replacing physicians with machines but rather creating a synergistic partnership in which human cognitive abilities are complemented by computational power and the analytical potential of artificial intelligence. The author's contribution lies in the systematization of cutting-edge developments in medicine and the identification of promising areas for further advancement, such as multimodal data integration, robotics, and neurointerfaces. The materials presented in this article will be valuable for medical professionals, AI researchers, and healthcare administrators.

Keywords: Diagnostic automation; Artificial intelligence; Machine learning; Medical technologies; Neural networks; Personalized medicine; Predictive analytics; Drug development; Robotics; Pharmaceutical solutions; Digital healthcare

1. Introduction

Modern healthcare faces numerous challenges, including the rising cost of medical services, a shortage of qualified personnel, an increasing prevalence of chronic diseases, and an aging population. It is important to highlight that traditional diagnostic and treatment methods often prove ineffective when dealing with complex pathologies. A major issue is the discrepancy between the exponentially growing volume of medical data and the limited human capacity for processing and interpreting it.

Given these considerations, artificial intelligence (AI) offers revolutionary solutions with the potential to resolve this imbalance and transform the landscape of 21st-century medicine. Currently, 75% of leading healthcare companies are experimenting with generative AI or planning to scale its implementation across their enterprises [1].

Under current conditions and with a forward-looking perspective, the integration of intelligent systems into clinical practice presents unique opportunities for a personalized approach to patient care, minimization of medical errors, and optimization of therapeutic strategies.

* Corresponding author: Sergiu Metgher

2. Materials and Methods

The analysis of sources on the studied topic has identified several key areas.

A significant portion of the literature is dedicated to the conceptual foundations and current state of artificial intelligence applications in medicine. M.P. Cote and co-authors [2] provide a fundamental characterization of basic AI concepts, emphasizing the importance of understanding the technical nuances of these technologies for their successful clinical implementation. Conversely, D.G. Katritsis [4] adopts a more critical stance, questioning both the "intelligence" and "artificiality" of modern AI systems in medicine, pointing to fundamental limitations in current approaches and the need for a more realistic assessment of their capabilities. Statistical data presented in the report [1] highlight the rapid growth of AI investments and implementation in healthcare, reflecting global trends in digitalization.

Another body of literature addresses the ethical, social, and structural aspects of AI integration into medical practice. A.J. London [6] explores whether artificial intelligence can overcome existing structural issues in healthcare or, conversely, exacerbate disparities in access to medical services. R. Skaria, P. Satam, and Z. Khalpey [8] examine AI's dual nature, identifying both unprecedented opportunities and significant challenges associated with its adoption.

A separate group of sources focuses on specific AI applications across various medical domains. The innovative Monarch platform [3] serves as an example of robotics and artificial intelligence integration for minimally invasive diagnostic and therapeutic procedures in pulmonology. The system combines robotic flexible endoscopy with AI-driven navigation through the bronchial tree, significantly improving the diagnostic accuracy of biopsies. The Tempus platform [9] demonstrates the use of AI in personalized medicine, integrating genomic, clinical, and radiological data to determine optimal treatment strategies, particularly in oncology.

Research on AI's role in the pharmaceutical industry and traditional medicine is of particular interest. D. Varol [10] analyzes transformations in drug discovery and development processes driven by artificial intelligence. X. Liu and T. Gong [5] offer an innovative perspective on integrating AI with evidence-based medicine. D.L. Mann [7] investigates AI's potential to accelerate the translation of fundamental scientific discoveries into clinical practice through an interdisciplinary approach.

A review of contemporary materials has revealed several significant gaps. The most apparent discrepancy lies between optimistic projections regarding AI's potential in medicine [1, 5, 7, 9] and more cautious, critical evaluations [4, 6, 8]. Insufficient attention has been given to the long-term economic efficiency of AI implementation and the challenges of preparing medical professionals to work with AI systems. Studies on patients' perceptions of emerging technologies across different sociocultural groups are virtually absent. Additionally, the impact of delegating clinical decision-making to AI systems on physicians' professional skills remains superficially explored.

The methodology includes literature reviews and conceptual analysis, processing of statistical data, systematization, and case study examination.

3. Results and Discussion

The integration of AI into the medical field has been developing for several decades; however, a true breakthrough has occurred only in recent years due to the convergence of several factors:

- Exponential growth in computational power;
- Advancements in machine learning algorithms;
- Accumulation of vast amounts of digital data.

The first expert systems developed in the 1970s, such as MYCIN for diagnosing infectious diseases, had highly limited functionality and did not gain widespread adoption. In contrast, modern neural network architectures demonstrate a fundamentally different level of effectiveness. Deep convolutional neural networks (CNNs) and transformers have revolutionized the field of computer vision, leading to direct applications in medical imaging and clinical text analysis [2, 5].

In the first quarter of 2024, a majority of executives in the healthcare sector reported that their organizations had either already implemented next-generation AI tools (29%) or were in the process of testing them (43%) [1]. Survey results on the adoption rate are presented in the diagram (Fig. 1).

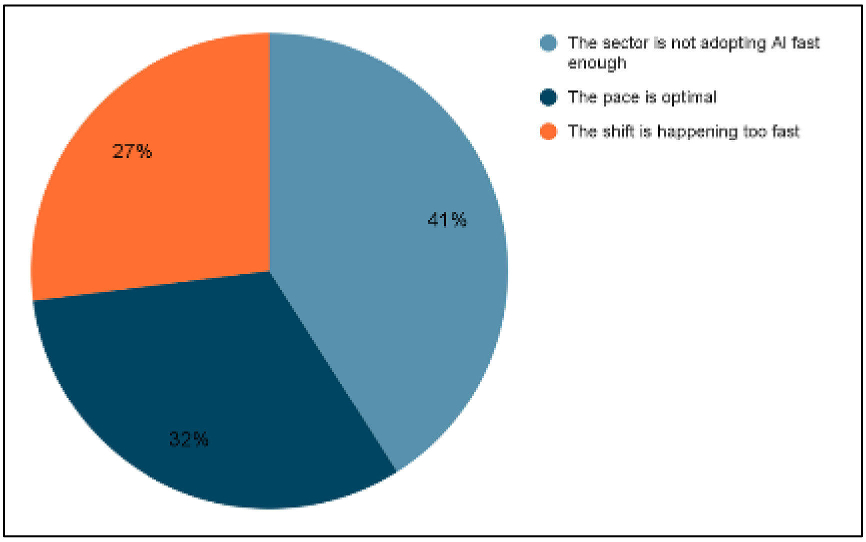

Figure 1 Respondents' opinions on the pace of AI implementation in the healthcare system (compiled by the author based on [1])

Diagnosis represents a fundamental stage of medical care, where accuracy is critically linked to the success of subsequent treatment. AI systems assist in interpreting various types of medical images, including X-rays, histological slides, and ultrasound scans.

Deep learning algorithms can detect early-stage malignant tumors in imaging scans, often identifying abnormalities that even experienced radiologists may overlook. In dermatology, neural network models have demonstrated unprecedented accuracy in recognizing melanoma, outperforming the average dermatologist in diagnostic precision. These programs analyze digital images of skin lesions and classify them based on risk levels [6, 8].

Beyond visual data, AI effectively processes unstructured text data within electronic medical records. Algorithms extract key clinical information from patient histories, laboratory results, and physician notes, forming a comprehensive overview of a patient's condition.

An innovative application of AI involves the automatic interpretation of bioacoustic signals, including heart sounds, respiratory noises, and other auditory phenomena recorded during clinical examinations. Digital stethoscopes with integrated machine learning algorithms can differentiate pathological heart murmurs with a high degree of accuracy.

The predictive capabilities of AI introduce new opportunities for managing chronic diseases and preventing acute conditions. Disease progression modeling based on complex parameter analysis enables timely adjustments to therapeutic interventions.

Machine learning algorithms demonstrate remarkable accuracy in predicting exacerbations of bronchial asthma and chronic obstructive pulmonary disease. By analyzing data from wearable monitoring devices, weather conditions, airborne allergen levels, and medication usage patterns, AI systems generate alerts about potential health deterioration 3–5 days before clinical symptoms appear.

In cardiology, AI algorithms analyze subtle variations in heart rate variability, detecting early signs of arrhythmias or acute coronary syndrome. Wearable ECG-enabled devices leverage built-in neural network models to identify atrial fibrillation, a condition that significantly increases the risk of ischemic stroke.

The traditional "one drug for all" approach is gradually being replaced by precise, individualized pharmacotherapy. AI systems analyze a patient's genetic profile, comorbidities, history of adverse reactions, and other factors to optimize medication prescriptions.

A notable example is the Tempus platform, which integrates genomic, clinical, and radiological data to determine the optimal therapeutic strategy for oncology patients. The system identifies specific molecular targets and predicts the efficacy of targeted drugs for individual patients [9].

Machine learning algorithms are also successfully applied to minimize adverse drug interactions in patients undergoing polypharmacy. These systems analyze the pharmacokinetic and pharmacodynamic properties of prescribed medications, alerting physicians to potentially hazardous combinations.

The traditional drug development process is characterized by high costs and long timelines. Implementing AI at all stages of research and development has the potential to radically transform this industry (Fig. 2).

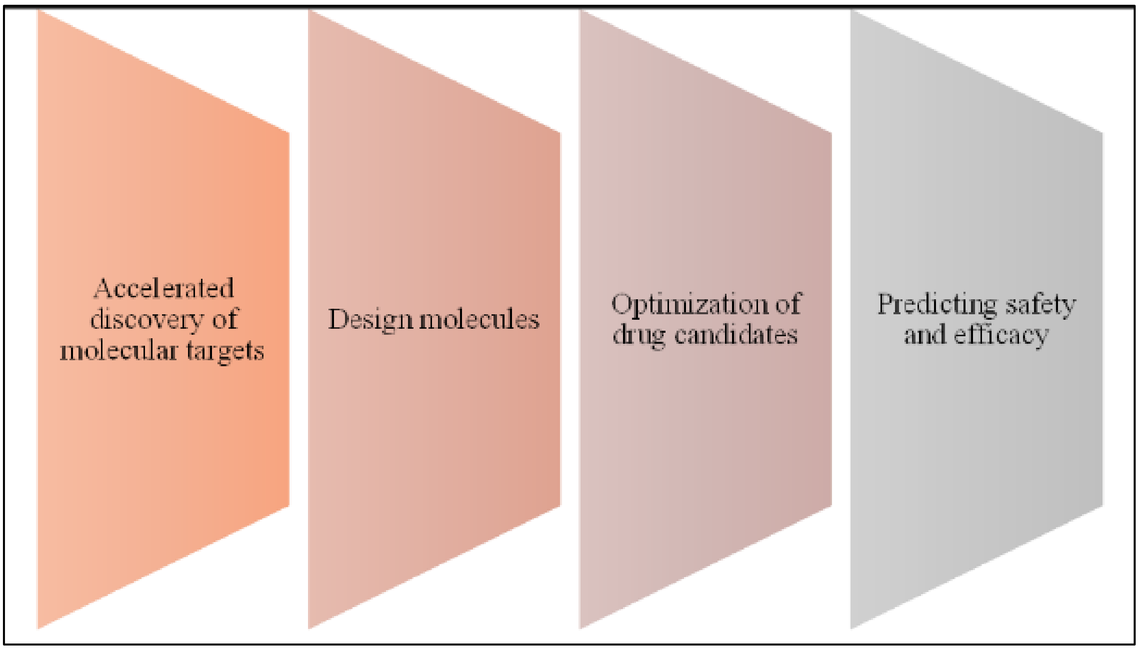

Figure 2 Drug development: a new paradigm combined with artificial intelligence (compiled by the author based on [4, 6, 10])

Machine learning algorithms effectively analyze transcriptomic, proteomic, and metabolomic data, identifying previously unknown molecular targets for therapeutic intervention. A revolutionary achievement in this field is the use of generative models for de novo molecular design. Instead of screening existing chemical compounds, AI generates entirely new structures optimized for specific targets.

Preclinical safety studies represent a critical stage in drug development, requiring significant time and financial resources. AI models predict potential toxicity and side effects based on the molecular structure of compounds, substantially reducing the number of components requiring experimental validation.

Despite AI's impressive potential in transforming medical practice, its implementation is accompanied by several ethical, legal, and social challenges:

- The "black box" problem and decision explainability;
- Protection of personal medical data;
- Accountability for clinical decisions.

Modern neural network architectures, particularly deep learning models, often function as a "black box," meaning the decision-making process remains unintuitive even for system developers. However, in clinical practice, transparency and explainability of diagnostic and therapeutic recommendations are critically important. To address this challenge, interpretable machine learning methods are being developed. Techniques such as Local Interpretable Model-Agnostic Explanations (LIME) and Shapley Additive Explanations (SHAP) enable visualization of which specific areas of a medical image or clinical factors contributed to a given conclusion.

The operation of AI systems requires access to vast amounts of personal data, which entails risks of privacy breaches. Federated learning technologies enable model training without centralized collection of sensitive information—the algorithm "travels" between different medical institutions, learning from local data while ensuring that the data itself remains stored securely at its original location.

Differential privacy and homomorphic encryption provide a mathematical framework that allows encrypted data to be processed without the need for decryption, thereby mitigating the risks of unauthorized access.

A significant issue remains the allocation of responsibility for clinical decisions made with AI involvement. In the event of an adverse outcome caused by an AI error, legal responsibility may fall on the system developer, the medical institution, the physician, or be distributed among them.

Regulatory authorities are developing specialized legislative frameworks to govern the certification of AI systems. The FDA (United States) and EMA (Europe) are implementing the concept of "adaptive pathways," which account for the continuous learning and evolution of algorithms.

The exponential advancement of artificial intelligence technologies is laying the groundwork for revolutionary transformations in medical practice in the coming years (Fig. 3).

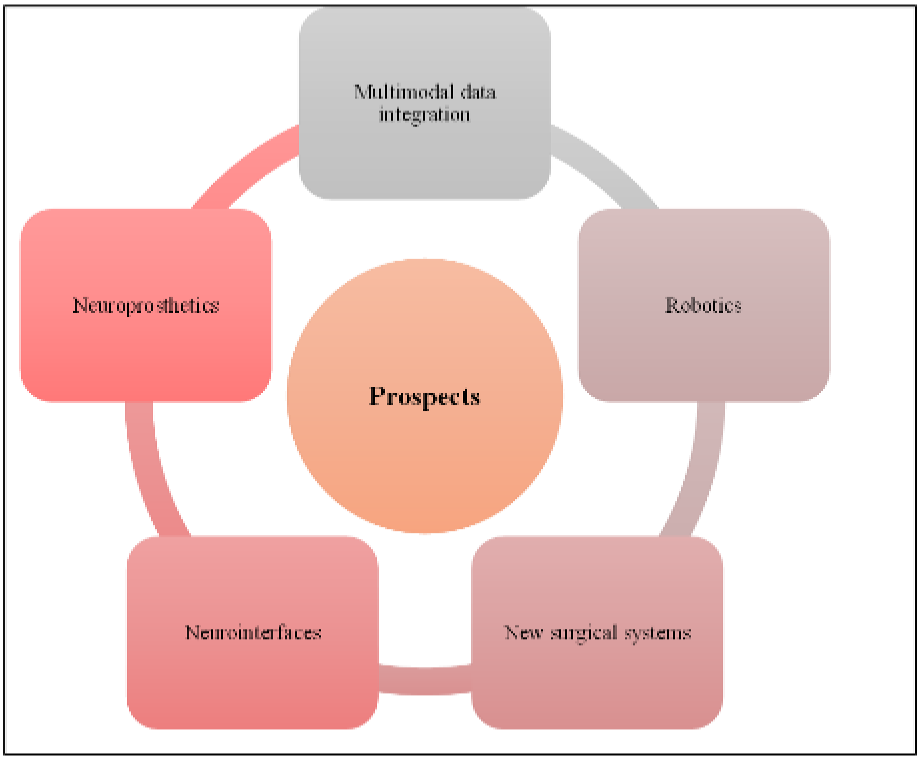

Figure 3 Prospects of using artificial intelligence in medical technologies (compiled by the author on the basis of [2, 4, 5, 8])

A clinical disease profile is composed of numerous heterogeneous data sources, including laboratory parameters, imaging results, genomic profiles, patient lifestyle, and other factors. Multimodal neural network architectures enable the integration of these diverse sources into a unified diagnostic and prognostic model.

A promising direction is the consolidation of data from genomics, transcriptomics, proteomics, metabolomics, and microbiomics to create a holistic representation of pathophysiological processes across all levels of biological organization.

The integration of computer vision, tactile feedback, and machine learning technologies offers additional opportunities in the field of robotic surgery. Next-generation systems are capable not only of replicating a surgeon's precise movements but also of actively assisting by compensating for natural hand tremors, alerting to potentially dangerous maneuvers, and suggesting optimal instrument trajectories.

For example, the Monarch Platform combines robotic flexible endoscopy with AI technologies to enable highly accurate biopsies of peripheral lung nodules that were previously difficult to access for diagnostic procedures [3].

Breakthrough neurointerface technologies, which establish direct connections between the brain and computational systems, present opportunities for restoring lost functions in patients with severe central nervous system damage. AI algorithms decode neural activity patterns, translating them into commands to control exoskeletons, prostheses, and external devices.

4. Conclusions

The integration of artificial intelligence into medical practice marks the beginning of a new era of personalized, predictive, and preventive medicine. The automation of routine diagnostic procedures, disease progression modeling, and revolutionary approaches to drug development are transforming the very paradigm of healthcare.

Despite significant technological and regulatory challenges, the potential of AI in preserving and improving human health is difficult to overestimate. The key to its successful integration into clinical practice lies not in replacing physicians with machines but in forming a synergistic partnership in which human cognitive abilities are complemented by the computational power and analytical potential of artificial intelligence.

The synthesis of medical knowledge accumulated over millennia with advanced data analysis algorithms presents an unprecedented opportunity to deepen the understanding of fundamental disease pathogenesis mechanisms and to develop innovative therapeutic approaches capable of significantly enhancing both the quality and longevity of patients' lives.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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