Use of Artificial Intelligence in Clinical Biochemistry

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Abstract
Traditionally, clinical biochemistry has relied on manual interpretation of laboratory test results, a process that can be time-consuming, susceptible to human error, and limited in scope. However, the integration of artificial intelligence (AI) technologies, including machine learning (ML) and deep learning, has significantly transformed this field. AI-driven predictive modeling offers medical professionals the ability to enhance treatment planning, anticipate disease progression, and reduce adverse outcomes. These technological advancements ultimately contribute to improved patient care and more efficient resource utilization. For this review, titled "Use of Artificial Intelligence in Biochemistry," an extensive literature search was conducted across multiple databases such as PubMed, Google Scholar, Scopus, and Web of Science. The search focused on articles published within the past decade, utilizing MeSH terms like (artificial intelligence) AND (clinical) AND (biochemistry), as well as additional keywords, including "machine learning," "deep learning," "biochemical analysis," and "clinical applications." The key characteristics of the selected studies are summarized in the accompanying table. Numerous studies have highlighted the transformative role of AI and ML across various medical and scientific disciplines. In Saudi Arabia, a cross-sectional study on the Saudi Human Genome Program (SHGP) found a generally positive perception regarding genetic data sharing and AI's role in data analysis and privacy regulation. In China and Japan, urine proteomics combined with ML facilitated the development of novel diagnostic panels for mild cognitive impairment (MCI) and Alzheimer's disease (AD), providing a non-invasive diagnostic alternative. Similarly, in the United States, ML-based urine metabolomics demonstrated high accuracy in predicting Renal Cell Carcinoma (RCC), underscoring AI's potential in precision medicine.
In Brazil, a platform integrating ML with mass spectrometry showed promise for rapid COVID-19 diagnosis and risk assessment. Additional research from Canada, Germany, Iran, and India has demonstrated ML's effectiveness in diverse areas, including oral microbiome characterization, proteomic profiling for muscle and fat mass, predicting neuropsychological responses to vitamin D supplementation, and assessing ChatGPT's ability to answer complex medical biochemistry questions. Furthermore, studies from Japan explored the potential of salivary metabolomics and ML for non-invasive breast cancer screening, while research from China and the U.S. focused on AI applications in diabetic kidney disease, melanocytic lesion analysis, and microbial community profiling. Collectively, these findings emphasize AI and ML's versatility in revolutionizing healthcare and advancing scientific knowledge.

Keywords: Clinical Biochemistry, Artificial Intelligence, Databases, Healthcare, Scientific understanding

Introduction

Artificial intelligence (AI) is revolutionizing clinical biochemistry by enhancing patient care, diagnostic accuracy, and research outcomes. As a multidisciplinary field, clinical biochemistry focuses on analyzing biological fluids and tissues to detect, monitor, and treat diseases. Traditionally, laboratory test results have been manually interpreted—a process that is time-consuming, prone to human error, and limited in scope. However, the integration of AI technologies, such as machine learning (ML) and deep learning, has significantly transformed the field. AI applications in clinical biochemistry span various domains, including drug discovery, automated test data interpretation, and predictive modeling for disease diagnosis and prognosis. One of AI's key strengths is its ability to process vast amounts of data from diverse sources—such as imaging studies, genetic sequencing, and electronic health records—to identify patterns and trends that may not be immediately apparent to human observers. This capability enables researchers and clinicians to develop targeted interventions tailored to individual patient needs, ultimately leading to more informed decision-making. In laboratory medicine, AI has streamlined test interpretation and result validation, reducing turnaround times, minimizing errors, and enhancing overall efficiency. Advanced AI systems can analyze complex biochemical data with high precision, making it easier to detect subtle abnormalities that may indicate underlying health conditions. Additionally, AI-powered decision support systems assist clinicians in evaluating test results,

selecting appropriate diagnostic tests, and formulating treatment plans based on clinical best practices and evidence-based guidelines.
Beyond laboratory applications, AI has reshaped disease diagnosis and management by facilitating early disease detection, patient risk assessment, and treatment outcome prediction. Machine learning algorithms can analyze clinical and laboratory data to identify biomarkers associated with specific diseases, allowing for early intervention and improved patient outcomes. Furthermore, AI-driven predictive modeling helps healthcare professionals optimize treatment plans, anticipate disease progression, and mitigate adverse outcomes. These advancements ultimately contribute to more effective patient care and the efficient utilization of healthcare resources.

Methodology:
For this review, titled *"Use of Artificial Intelligence in Biochemistry,"* a comprehensive literature search was conducted across multiple databases, including PubMed, Google Scholar, Scopus, and Web of Science, to identify relevant articles published in the past ten years. The search strategy incorporated MeSH terms such as *(artificial intelligence) AND (clinical) AND (biochemistry)*, along with additional keywords like "machine learning," "deep learning," "biochemical analysis," and "clinical applications."
The initial screening involved evaluating titles and abstracts to identify potentially relevant studies, followed by a full-text review to determine eligibility based on predefined inclusion and exclusion criteria. Data extraction was performed independently by two reviewers, focusing on study objectives, AI techniques employed, biochemistry domains explored, clinical applications, outcomes, limitations, and conclusions. The findings were synthesized narratively to highlight key themes, emerging trends, and research gaps, while a quantitative meta-analysis was considered where appropriate.

Inclusion criteria:
This review includes studies that explore the application of artificial intelligence (AI) techniques in biochemistry, specifically those utilizing machine learning, deep learning, neural networks, or other AI algorithms for analyzing, interpreting, or predicting biochemical data. The focus is on clinical applications of AI in biochemistry, including disease diagnosis, prognosis, treatment optimization, biomarker discovery, drug development, and personalized medicine. The inclusion criteria cover research studies such as clinical trials and clinical studies. To ensure quality and reliability, only articles published in peer-reviewed journals or reputable conference proceedings were considered.

Exclusion criteria:
The exclusion criteria encompassed non-clinical studies, narrative reviews, short communications, editorials, and letters to the editor. Additionally, non-English articles, dissertations, theses, commentaries, and conference abstracts without full-text availability were excluded. To ensure the integrity and uniqueness of the included studies, duplicate publications, overlapping datasets, and articles reporting redundant information were also omitted.

Results:
1. Privacy Regulation and Genetic Data Analysis
The study sought to assess the Saudi Human Genome Programme (SHGP) and the function of artificial intelligence (AI) in the processing of genetic data and the management of privacy in Saudi Arabian society. The findings revealed a largely favorable disposition towards SHGP outcomes and the dissemination of genetic data for scientific and medical research. Participants exhibited a significant understanding of AI's role in genetic data processing and privacy protection, highlighting its potential to facilitate informed choice-making in genomic research.
Similarly, a study in Canada examined the predictive effectiveness of machine learning techniques for caries prediction using next-generation sequencing data from dental plaque and oral swab samples. Results demonstrated the feasibility of classifying samples based on sampling locations and caries status, contributing to the advancement of personalized oral healthcare strategies.

2. Metabolomics for Disease Identification and Risk Assessment
Chinese researchers have emphasized the significance of serum myoglobin (Mb) in the advancement of diabetic kidney disease (DKD). Feature significance analysis demonstrated a robust link between diabetic kidney disease (DKD), increased blood myoglobin (Mb) levels, and elements of metabolic syndrome, underscoring Mb's potential as a biomarker for the management and progression of DKD. In Japan, salivary biomarkers were investigated as a non-invasive approach to differentiate breast cancer patients from healthy persons. Research indicated that salivary metabolomics, in conjunction with ADTree-based machine learning methods, has the potential to revolutionize early detection approaches for breast cancer screening. A 14-year

longitudinal study in Germany found new protein biomarkers linked to low muscle mass, high fat mass, and their combination. Proteomic profiling identified biomarkers indicative of alterations in muscle and adipose tissue, providing insights into metabolic health and prospective therapeutic targets.
A research in Saudi Arabia evaluated the Saudi Human Genome Programme (SHGP) and the use of AI in genetic data processing and privacy control. Results demonstrated a predominantly favorable disposition towards SHGP findings and the exchange of genetic material for research objectives. Participants exhibited a significant understanding of AI's applications in genetic data processing and privacy protection, highlighting its potential for informed decision-making in genomic research.

Proteomic Profiling
Researchers in China and Japan utilized urine proteomics and machine learning to identify novel diagnostic panels for the early detection of Alzheimer's disease (AD) and mild cognitive impairment (MCI). This approach offers a convenient, non-invasive, and effective diagnostic tool for early intervention. In Iran, a study employed artificial neural network techniques to assess the relationship between neuropsychological indicators and the response to vitamin D supplementation. The developed model enables personalized optimization of cognitive performance and health outcomes by accurately predicting responsiveness to vitamin D treatment.
In the United States, researchers employed liquid chromatography-mass spectrometry (LC-MS) and nuclear magnetic resonance (NMR) data, integrated with machine learning, to find potential metabolomic panels for Renal Cell Carcinoma (RCC).
The resulting seven-metabolite panel demonstrated high accuracy, sensitivity, and specificity in predicting RCC status, highlighting its potential as a reliable diagnostic tool for kidney cancer.
In Brazil, scientists developed a rapid platform for COVID-19 detection in plasma samples by integrating machine learning with mass spectrometry. The model exhibited strong diagnostic potential, with biomarker-based comparisons enhancing its robustness and applicability for real-world screening.

AI in Medical Education
Researchers in India assessed ChatGPT's ability to respond to more complex queries related to medical biochemistry (17). The study demonstrated ChatGPT's usefulness in medical education and problem-solving, highlighting its potential as an effective tool for handling challenging inquiries in the field.

Recommendation
In order to improve patient care and research, artificial intelligence (AI) must be incorporated into healthcare policy frameworks. Governments and healthcare organizations need to make this integration a top priority by funding AI research and encouraging partnerships between the private sector, academic institutions, and healthcare providers. To protect patient privacy and safety while using AI in clinical settings, there must be clear criteria. It is crucial to fund educational and training initiatives in order to give medical personnel the know-how and abilities they need to use AI technologies efficiently. AI tools for patient care and research can be practically used through specialized training programmes and workshops. Healthcare organizations may enable their staff to fully utilize AI's potential to enhance clinical outcomes by investing in AI education and training.

S.No	Study Titles	Year	Site	Objective	Outcome
1	Genetic data sharing and artificial intelligence in the era of personalized medicine based on a cross-sectional analysis of the Saudi human genome program(9)	2022	Saudi Arabia	to examine the awareness, knowledge, and attitude of the Saudi society towards the SHGP, the sharing and privacy of genetic data resulting from the SHGP, and the role of AI in genetic data analysis and regulations.	A generally positive attitude was found towards the outcomes of the SHGP and genetic data sharing for medical and scientific research. The highest level of knowledge was detected regarding AI use in genetic data analysis and privacy regulation.
2	Identification of novel diagnostic panel for mild cognitive impairment and Alzheimer's disease: findings based on urine proteomics and	2023	China/Japan	The aim was to conduct an analysis based on urine proteomics and machine learning to identify novel diagnostic panels for early diagnosis of MCI and AD.	The procedure is convenient, non-invasive, and useful for diagnosis, which could assist physicians in differentiating AD and MCI from CN.

	machine learning(13)				
3	Machine Learning-Enabled Renal Cell Carcinoma Status Prediction Using Multiplatform Urine-Based Metabolomics(18)	2021	USA	we acquired liquid chromatography-mass spectrometry (LC-MS) and nuclear magnetic resonance (NMR) data followed by the use of machine learning (ML) to discover candidate metabolomic panels for RCC	A seven-metabolite panel predicted RCC in the test cohort with 88% accuracy, 94% sensitivity, 85% specificity, and 0.98 AUC.
4	Covid-19 Automated Diagnosis and Risk Assessment through Metabolomics and Machine Learning(16)	2021	Brazil	The aim was to integrate machine learning with mass spectrometry to develop a rapid platform for identifying COVID-19 in plasma samples in minutes	The pairwise analysis of biomarkers brought robustness to the model developed using machine learning algorithms, transforming this screening approach in a tool with great potential for real-world application.
5	Characterization of Supragingival Plaque and Oral Swab Microbiomes in Children With Severe Early Childhood Caries(19)	2021	Canada	This study aimed to determine which of two commonly used sampling sites (dental plaque vs. oral swab) would provide a better prediction model for caries-free vs. severe early childhood caries (S-ECC) using next generation sequencing and machine learning (ML)	ML approaches revealed the possibility of classifying samples according to both caries status and sampling sites. The tested site of sample collection did not change the predictability of the disease.
6	Proteomic profiling of low muscle and high fat mass: a machine learning approach in the KORA S4/FF4 study(12)	2021	Germany	The aim of this study is to identify new protein biomarkers of low muscle, high fat mass, and their combination as well as their changes over a 14-year follow-up period.	Proteomic profiling revealed CCL28 and TIMP4 as new biomarkers of low muscle mass combined with high fat mass and NT-proBNP as a key biomarker of loss in muscle mass combined with gain in fat mass.
7	The relationship between neuropsychological function and responsiveness to vitamin D supplementation using artificial neural networks(10)	2020	Iran	We aimed to assess the association between several neuropsychological parameters and the magnitude of response to vitamin D supplementation using an artificial neural network method.	The artificial neural network algorithm with sigmoid transfer function in both hidden and output layers could predict responsiveness to vitamin D supplementation effectively. The sensitivity and specificity were between 0.60 and 0.70 and 0.66 and 0.70, respectively.
8	Evaluating ChatGPT's Ability to Solve Higher-Order Questions on the Competency-Based Medical Education Curriculum in Medical Biochemistry(17)	2023	India	This research aimed to evaluate ChatGPT's aptitude for responding to higher-order questions on medical biochemistry.	The results of this research indicate that ChatGPT has the potential to be a successful tool for answering questions requiring higher order thinking in medical biochemistry, with a median score of four out of five.
9	Salivary metabolomics with alternative decision tree-based machine learning methods for breast cancer discrimination(14)	2019	Japan	The aim of this study is to explore new salivary biomarkers to discriminate breast cancer patients from healthy controls.	The study indicates that combinations of salivary metabolomics with the ADTree-based machine learning methods show potential for non-invasive screening of breast cancer.
10	Identifying myoglobin as a mediator of diabetic kidney disease: a machine learning-	2022	China	We aimed to elucidate the significance of serum Mb in the pathogenesis of Diabetic kidney disease.	In our study, feature importance analysis, SHAP, and RCS revealed that MetS components and elevated serum Mb were closely related to DKD

	based cross-sectional study(11)				
11	Population-Based Analysis of Histologically Confirmed Melanocytic Proliferations Using Natural Language Processing(20)	2018	USA	To determine population-based frequencies and distribution of histologically confirmed melanocytic lesions.	Approximately one-quarter of skin biopsies resulted in diagnoses of melanocytic proliferations. These data provide the first population-based estimates across the spectrum of melanocytic lesions ranging from benign through dysplastic to malignant.
12	Machine learning performance in a microbial molecular autopsy context: A cross-sectional postmortem human population study(15)	2019	USA	we aimed to evaluate machine learning methods performance of microbial community analyses developed from a large-scale survey of postmortem samples	All algorithms performed well but with distinct features to their performance. Xgboost often produced the most accurate predictions but may also be more prone to overfitting. Random forest was the most stable across predictions that included more anatomic areas.

Conclusion

In conclusion, the application of artificial intelligence (AI) in clinical biochemistry holds significant potential to transform patient care, enhance diagnostic accuracy, and advance biomedical research. By integrating machine learning, deep learning, and other AI-driven technologies, healthcare practitioners can harness data analytics to make evidence-based decisions, optimize treatment regimens, and improve patient outcomes. However, to ensure the ethical use of AI, regulatory compliance, and widespread adoption, ongoing research, standardized guidelines, and robust validation frameworks are essential. Addressing these challenges will help maximize AI’s benefits while maintaining patient safety, data security, and clinical reliability. adoption, legislators, healthcare organizations, and educational institutions must work together to successfully apply AI in clinical biochemistry. We can fully utilize AI to revolutionize clinical biochemistry and improve healthcare delivery globally if we continue to invest in AI research and teaching.

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