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Artificial Intelligence-Assisted Blood Biomarker Analysis for Early Detection of Alzheimer's Disease

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Abstract. Alzheimer's disease (AD) ranks among the most prevalent neurodegenerative diseases globally, and definitive diagnosis is frequently accomplished subsequent to substantial brain damage. Conventional diagnostic methods, including positron emission tomography (PET) imaging and cerebrospinal fluid (CSF) analysis, yield satisfactory diagnostic performance but suffer from high costs and invasiveness. In recent years, blood biomarkers such as amyloid-beta (Aβ), phosphorylated tau (p-tau), and neurofilament light chain (NfL) have emerged as promising tools for earlier and more accessible diagnosis. However, interpreting complex biomarker data remains challenging. Each marker reflect distinct neurodegenerative problem. Artificial intelligence (AI) and machine learning techniques may improve diagnostic accuracy by analyzing multiple biomarkers simultaneously and identifying hidden biological patterns. This paper reviews the role of AI-assisted blood biomarker analysis in the early diagnosis of Alzheimer's disease, discusses major biomarkers currently used in research, summarizes recent findings, and evaluates the opportunities and limitations of AI-based diagnostic approaches. Although several challenges remain, including dataset bias and clinical implementation difficulties, AI-assisted blood testing represents a promising direction for improving large-scale screening and early intervention for Alzheimer's disease. It may also reduce reliance on costly, invasive examinations in healthcare.

Keywords: Alzheimer, blood biomarker, artificial intelligence, early diagnosis

1. Introduction

Alzheimer's disease (AD) is one of the most widespread neurodegenerative diseases in the world and constitutes the predominant type of dementia. It gradually impairs memory, cognition, and daily functioning, eventually leading to severe loss of independence. As global population continue to age, the number of people affected by Alzheimer's disease is increasing rapidly, creating significant medical, social, and economic challenges. AD gradually damages memory, thinking ability, and daily functioning, eventually leading to severe cognitive decline and loss of independence. Because it is a kind of degenerative disease, current treatments are more effective during the earlier stages. Therefore, early diagnosis is one of the most important goals in Alzheimer's disease research.

Traditionally, Alzheimer's disease has been diagnosed using brain imaging techniques such as positron emission tomography (PET) scans or through cerebrospinal fluid (CSF) analysis. Although

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these methods can provide accurate information about amyloid-beta and tau pathology in the brain, they are expensive, invasive, and not easily accessible for large-scale population screening [1]. Consequently, researchers have increasingly turned their attention to blood-based biomarkers, which offer a less invasive, more affordable and more scalable alternative for early detection. Blood-based biomarker tests are especially promising because they are easier to perform in routine clinical settings compared to PET imaging or spinal fluid collection [2, 3].

However, interpreting blood biomarker data remains challenging. Alzheimer's disease is biologically complex ,and biomarkers may vary across different individuals. To address this challenge, researchers have increasingly explored artificial intelligence (AI) and machine learning techniques because these methods can analyze multiple biomarkers simultaneously and identify hidden patterns that may not be easily recognized through traditional statistical approaches [4]. Recent studies suggest that AI-assisted biomarker analysis may improve early disease detection, distinguish Alzheimer's disease from normal aging, and help predict cognitive decline in patients with mild cognitive impairment [5].

Despite these promising findings, important limitations remain. Many AI models contain limited datasets that may not fully represent diverse populations, and differences in laboratory testing methods can affect the reliability of biomarker measurements [6]. Therefore, this paper examines how AI can assist the early diagnosis of Alzheimer's disease through the analysis of blood biomarkers and discusses the major opportunities and limitations of using AI.

2. Major blood biomarkers in Alzheimer's disease

A range of blood biomarkers has become increasingly important in Alzheimer's disease research. The three most extensively investigated biomarkers are amyloid-beta (Aβ), phosphorylated tau (p-tau), and neurofilament light chain (NfL). These biomarkers correspond to various biological processes implicated in neurodegeneration, which could facilitate the identification of Alzheimer's disease before severe symptoms develop.

The formation of cerebral amyloid plaques is associated with amyloid-beta proteins, and such plaques are constituted one of the representative hallmarks of Alzheimer's disease. These plaque aggregates disrupt neuronal communicationand gradually impair cognitive function. Changes in the ratio between Aβ42 and Aβ40 in blood plasma have been linked to amyloid accumulation in the brain [1]. However, amyloid-beta alone may not provide sufficient diagnostic accuracy because amyloid accumulation can also occur in some cognitively normal older adults.

Phosphorylated tau proteins, especially p-tau217 and p-tau181, have recently shown strong potential as blood biomarkers for Alzheimer's disease. High plasma p-tau concentration are closely associated with tau pathology and neuronal damage. Hansson et al. [2] demonstrated that plasma p-tau217 assays showed promising diagnostic performance and may help distinguish Alzheimer's disease from other neurodegenerative disorders.

Neurofilament light chain (NfL) is a structural protein abundant in the axons of neurons. It is another important biomarker that reflects neuronal injury and neurodegeneration. Increased NfL levels have been observed in several neurological diseases, including Alzheimer's disease [3]. Although NfL is not specific to Alzheimer's disease, combining NfL with other biomarkers may improve overall diagnostic performance.

Because Alzheimer's disease involves multiple biological pathways, researchers increasingly believe that combining several biomarkers may provide more accurate diagnostic information than relying on a single marker alone.

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3. AI and machine learning applications in biomarker analysis

Artificial intelligence and machine learning methods are becoming increasingly important in Alzheimer's disease research because they are capable of analyzing large-scale and complex datasets with higher efficiency compared with conventional statistical approaches. AI systems are particularly useful when multiple biomarkers must be interpreted simultaneously.

Machine learning models can identify hidden relationships between biomarker levels, patient characteristics, and disease progression. Different computational approaches, including logistic regression, support vector machines, random forests, and neural networks, have been applied to Alzheimer's disease diagnosis [4]. These models are trained on biomarker data collected from healthy subjects, individuals suffering from mild cognitive impairment, and patients with a confirmed diagnosis of Alzheimer's disease.

AI-assisted analysis may improve diagnostic accuracy in several ways. First, AI models can detect subtle biomarker changes that may be difficult for humans to recognize. Subtle biomarker changes may emerge before obvious cognitive symptoms arise. Second, machine learning algorithms can integrate multiple biomarkers into a single predictive model rather than evaluating each marker separately. Third, AI systems may help predict whether individuals with mild cognitive impairment will later develop Alzheimer's disease. This offers valuable reference for early clinical intervention.

Recent studies have reported encouraging findings regarding AI-assisted biomarker analysis. Kivisäkk et al. [5] showed that combining plasma biomarkers improved the prediction of cognitive decline in patients with mild cognitive impairment. Similarly, Chang et al. [4] discussed how machine learning models may support earlier and more accurate diagnosis by integrating multiple sources of biological information.

In addition to improving diagnostic performance, AI-based blood testing may also reduce healthcare costs and increase accessibility. Compared to PET scans and CSF analysis, blood tests are easier to perform and may eventually support large-scale population screening programs.

4. Current challenges and future directions

Although AI-assisted blood biomarker analysis shows significant promise for Alzheimer's disease diagnosis, several scientific and clinical challenges still need to be addressed before these technologies can become widely adopted in routine healthcare settings.

One major challenge involves the quality and diversity of training datasets used in machine learning models. Many current studies rely on relatively small datasets, often consisting primarily of older white individuals from developed countries. As a result, AI models trained on these datasets may not generalize well to populations with different genetic backgrounds, environmental exposures, or healthcare conditions [6]. Without more inclusive datasets, AI models may not generalize well to global populations. Future studies should therefore focus on building larger and more ethnically diverse datasets to improve model reliability and reduce potential bias.

Another important issue is biomarker standardization. Blood biomarker measurements may vary between laboratories because of differences in assay platforms, sample handling methods, and data processing techniques. Even small variations in laboratory procedures may affect biomarker concentrations and reduce the reliability of AI predictions. Standardized testing protocols and international guidelines will likely be necessary before AI-assisted blood testing can be broadly implemented in clinical practice.

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Interpretability also remains a challenge for many machine learning systems. Some advanced AI models, particularly deep neural networks, are often considered "black box" systems because their internal decision-making processes are difficult to explain. In clinical medicine, physicians and patients may hesitate to trust diagnostic predictions that cannot be clearly interpreted. Researchers are therefore increasingly interested in developing explainable AI approaches that improve transparency while maintaining strong predictive performance.

In addition, most current studies focus primarily on diagnostic classification rather than long-term disease monitoring. Future AI systems may not only identify Alzheimer's disease at earlier stages but also help predict disease progression, treatment response, and cognitive decline over time. Integrating blood biomarkers with additional data sources, such as cognitive testing, genetic risk factors, brain imaging, and wearable device data, may further improve prediction accuracy and provide a more holistic understanding of disease progression.

Finally, ethical and regulatory concerns will play an important role in the future development of AI-assisted diagnosis. Questions involving patient privacy, informed consent, data security, and the psychological effects of early disease prediction remain important considerations. Because Alzheimer's disease currently has limited curative treatment options, early diagnosis may sometimes create emotional stress or anxiety for patients and families. Clear clinical guidelines and strong patient support systems will therefore be essential as AI-assisted diagnostic technologies continue to develop.

5. Discussion

AI-assisted blood biomarker analysis has several important advantages in Alzheimer's disease diagnosis. Blood tests are less invasive, less expensive, and more widely accessible than traditional imaging techniques or spinal fluid collection. AI can simultaneously analyze multiple biomarkers, including Aβ, p-tau and NfL thereby further improving diagnostic efficiency. Because of these advantages, blood-based screening may eventually allow earlier detection of individuals at risk for Alzheimer's disease, especially in primary healthcare settings or regions with limited medical resources.

Another major advantage is the ability of AI models to analyze highly complex biological data. Alzheimer's disease is influenced by multiple pathological processes, and AI may help integrate information from different biomarkers simultaneously. This may improve diagnostic accuracy compared to approaches that rely on only one biomarker.

However, several important limitations still exist. One major challenge is dataset bias. Many current AI models are trained using data collected primarily from older white populations, which may reduce their reliability when applied to more diverse populations [6]. Differences in laboratory methods may also affect biomarker measurements and reduce reproducibility of findings across studies.

Another limitation is that strong performance in research settings does not always guarantee successful clinical implementation. Some machine learning models may become overfitted to specific datasets and perform less accurately in real-world hospitals. In addition, AI-assisted diagnosis raises ethical concerns, including data privacy, false positive diagnoses, and the psychological impact of early disease prediction.

Ultimately, these advances may supports earlier intervention before irreversible cognitive impairment develops. Despite these limitations, AI-assisted blood biomarker analysis remains a highly promising research direction. As larger and more diverse datasets become available, machine learning models will likely become more reliable and clinically useful. Continued collaboration

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between neuroscientists, clinicians, and computational researchers will be essential for translating these technologies into practical medical tools.

6. Conclusion

In conclusion, artificial intelligence-assisted blood biomarker analysis represents a promising new approach for the early detection of Alzheimer's disease. Blood biomarkers such as amyloid-beta, phosphorylated tau, and neurofilament light chain provide valuable biological information about neurodegeneration, while AI and machine learning models may improve the interpretation of complex biomarker data.

Compared to traditional diagnostic methods such as PET imaging and CSF analysis, blood-based testing offers important advantages in cost, accessibility, and scalability. AI-assisted analysis may also support earlier intervention by identifying subtle disease-related patterns before severe symptoms appear.

Although several challenges remain, ongoing advances in biomarker research and machine learning technology continue to improve the potential of AI-assisted diagnosis. Future research should prioritize the validation of these methods in larger and more diverse populations and improving the integration of AI systems into real-world clinical practice. With sustained cross-disciplinary collaboration between neuroscientists and data researchers, this diagnostic approachmay eventually achieve widespread clinical adoption.

References

[1] Jack, C. R., Jr., Bennett, D. A., Blennow, K., Carrillo, M. C., Dunn, B., Haeberlein, S. B., Holtzman, D. M., Jagust, W., Jessen, F., Karlawish, J., Liu, E., Molinuevo, J. L., Montine, T., Phelps, C., Rankin, K. P., Rowe, C. C., Scheltens, P., Siemers, E., Snyder, H. M., & Silverberg, N. (2018). Nia-aa research framework: Toward a biological definition of Alzheimer's disease. *Alzheimer's & Dementia, 14*(4), 535–562. https://doi.org/10.1016/j.jalz.2018.02.018

[2] Hansson, O., Cullen, N. C., Zetterberg, H., Blennow, K., & Mattsson-Carlgren, N. (2021). Diagnostic performance of a plasma phosphorylated tau 217 assay for Alzheimer's disease. *Nature Medicine, 27*(1), 107–114. https://www.nature.com/articles/s41398-026-04043-0

[3] Khalil, M., Teunissen, C. E., Otto, M., Piehl, F., Sormani, M. P., Gattringer, T., Barro, C., Kappos, L., Comabella, M., Fazekas, F., Petzold, A., Blennow, K., & Zetterberg, H. (2018). Neurofilaments as biomarkers in neurological disorders. *Nature Reviews Neurology, 14*(10), 577–589. https://doi.org/10.1038/s41582-018-0058-z

[4] Chang, C. H., Lane, H. Y., & Lin, C. H. (2021). Machine learning and novel biomarkers for the diagnosis of Alzheimer's disease. *International Journal of Molecular Sciences, 22*(9), 4571. doi: 10.3390/ijms22052761

[5] Kivisäkk, P., Ashton, N. J., Benedet, A. L., Pascoal, T. A., Karikari, T. K., Lantero-Rodriguez, J., Snellman, A., Schöll, M., Blennow, K., Zetterberg, H., & Palmqvist, S. (2023). Plasma biomarkers for diagnosis of Alzheimer's disease and prediction of cognitive decline in individuals with mild cognitive impairment. *Frontiers in Neurology, 14*, 1069411. https://doi.org/10.3389/fneur.2023.1069411

[6] Therriault, J., Schindler, S. E., Salvadó, G., Pascoal, T. A., Benedet, A. L., Ashton, N. J., Karikari, T. K., Apostolova, L., Murray, M. E., Verberk, I. M. W., Vogel, J. W., La Joie, R., Gauthier, S., Teunissen, C. E., Rabinovici, G. D., Zetterberg, H., Bateman, R. J., Scheltens, P., Blennow, K., Sperling, R., Hansson, O., Jack, C. R., Jr., & Rosa-Neto, P. (2024). Biomarker-based staging of Alzheimer disease: Rationale and clinical applications. *Nature Reviews Neurology, 20*(4), 232–244. https://doi.org/10.1038/s41582-024-00942-2