

Bridging artificial intelligence and liquid biopsy in cancer research: methodological approaches

Abstract Submitter: Brune De Dreuille, Spain*

Co-Authors: Brune de Dreuille, Mireia Andueza-Peral, Pablo Villoslada-Blanco, Lola Alonso, Sergio Sabroso-Lasa, Evangelina López de Maturana, Núria Malats

*Spanish National Cancer Research Centre

Abstract

Cancer is a global health challenge, ranking as the second leading cause of death with rising incidence and mortality. A key factor influencing patient outcomes is minimal residual disease (MRD) detection. Early and accurate MRD detection enables timely intervention, improving prognosis and reducing mortality. Liquid biopsy (LB), a non-invasive tool that analyses tumor-derived biomarkers in body fluids, has emerged as a powerful method for monitoring MRD. However, its sensitivity depends on processing vast, complex molecular data from high-throughput sequencing platforms. Additionally, managing longitudinal data across multiple time points adds complexity, as biomarker-level variations need accurate interpretation, accounting for intra-patient heterogeneity and technical variability. In this context, Artificial Intelligence (AI) is key in integrating the complex data from LB tests. However, the literature is sparse in studies integrating LB features, likely due to the complexity of AI-based integrative methodologies, cost constraints, or the lack of standardization among LB assays. Therefore, we aimed to evaluate advancements in AI-driven MRD detection using LB and provide guidelines for incorporating AI techniques in this area.

For AI-based MRD detection, defining study objectives is crucial, as they guide methodological decisions such as study design, patient selection, clinical/epidemiological data collection and statistical analysis of LB features. The latter may require the integration of omics features of multiple modalities, which may imply the application of machine learning (ML) methods. Implementing ML algorithms involves previous and critical steps like harmonizing and normalizing data from different sources, correcting batch effects, and addressing outliers and missing data. Thereafter, the selection of the best model will come after benchmarking different ML fusion strategies (e.g., early or late fusion). In particular, AI models, such as deep learning and probabilistic approaches, including recurrent neural networks or hidden Markov models, can capture temporal dependencies to enhance the predictive accuracy of MRD detection over time. Then, the selected ML algorithm model must undergo rigorous external validation. Finally, it is essential to assess clinical utility and interpretability, often overlooked but vital for real-world implementation.

Given the scarcity of research integrating AI with LB-based MRD detection, we provide a structured methodological approach to bridge both fields.

Do you have any conflicts of interest?

No, I do not have a conflict of interest.