Perspective

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Liquid Biopsies as the Next Standard in Cancer Screening and Surveillance

Bonneville Iquebal*

Department of Cancer Immunotherapy, University College London, London, United Kingdom

***Correspondence to**: Bonneville Iquebal, Department of Cancer Immunotherapy, University College London, London, United Kingdom, E-mail: bonnevillequebal@aeo.uk

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Introduction

Cancer remains one of the most formidable health challenges of the modern era, with early detection and effective monitoring of disease progression being critical to improving patient outcomes. Traditional diagnostic modalities, such as tissue biopsies, imaging, and cytological examinations, though indispensable, are often invasive, limited in scope, and may not fully capture tumor heterogeneity or disease evolution over time. In this context, liquid biopsies—a minimally invasive approach that analyzes circulating tumor-derived components in bodily fluids such as blood, urine, or saliva—have emerged as a transformative technology in oncology. By detecting circulating tumor DNA (ctDNA), Circulating Tumor Cells (CTCs), extracellular vesicles, and other molecular biomarkers, liquid biopsies provide real-time insights into the genetic and epigenetic landscape of cancer. The promise of liquid biopsy lies not only in its ability to detect malignancies earlier than conventional methods but also in its capacity to track treatment response, identify resistance mutations, and monitor disease recurrence with high precision. As cancer screening and surveillance continue to evolve, liquid biopsy stands poised to become the next clinical standard, bridging the gap between personalized medicine and population-wide cancer control strategies [1].

Description

One of the most compelling advantages of liquid biopsy lies in its potential for early cancer detection, a stage at which therapeutic interventions are most effective. Screening approaches using ctDNA-based assays have demonstrated the ability to detect cancers months or even years before clinical symptoms appear. For example, large-scale studies employing Multi-Cancer Early Detection (MCED) tests have shown promise in identifying malignancies across various tissue types using a single blood draw, primarily by profiling DNA methylation signatures unique to tumors. Unlike tissue biopsy, which is constrained by the accessibility of tumor tissue, liquid biopsy provides a systemic view of tumor activity, capturing signals even from tumors located in anatomically challenging regions such as the pancreas, ovaries, or brain. This non-invasive nature makes it particularly attractive for widespread population-level screening, where patient compliance is critical [2].

Beyond detection, liquid biopsies are revolutionizing cancer surveillance by enabling longitudinal monitoring of disease dynamics. In patients undergoing treatment, serial measurements of ctDNA levels can serve as a surrogate for tumor burden, offering a sensitive measure of response to therapy. For instance, declining ctDNA levels during targeted therapy or immunotherapy often correlate with radiological regression, whereas rising ctDNA levels may precede imaging-detectable progression by weeks to months. This provides clinicians with a valuable lead time to adapt treatment strategies. Additionally, liquid biopsy has demonstrated utility in detecting Minimal Residual Disease (MRD) after surgery or curative-intent therapy, identifying patients at high risk of recurrence long before clinical relapse is evident. In colorectal, lung, and breast cancers, MRD monitoring through ctDNA assays has already shown potential to guide adjuvant therapy decisions, marking a paradigm shift in personalized oncology. The role of liquid biopsy in identifying mechanisms of therapeutic resistance further highlights its clinical value. Tumors often develop secondary mutations or activate alternative signaling pathways that render targeted therapies ineffective [3].

From a technological perspective, advancements in sequencing methods and bioinformatics have enhanced the sensitivity and specificity of liquid biopsy assays. Ultra-deep sequencing and error suppression algorithms now allow for the reliable detection of mutations present at very low allele frequencies, crucial for early-stage cancers where ctDNA is scarce. Moreover, integrating multiple analytes—such as combining ctDNA mutation analysis with methylation profiling, fragmentomics, or exosome RNA signatures—has significantly improved diagnostic accuracy. Artificial intelligence (AI) and machine learning models further refine biomarker interpretation, enabling multi-dimensional analysis of liquid biopsy data to distinguish malignant from benign signals with high confidence. The clinical adoption of liquid biopsy also carries important implications for healthcare accessibility and patient experience. Unlike tissue biopsies, which require invasive procedures, anesthesia, and hospitalization, liquid biopsies can be performed with a simple blood draw in outpatient settings [4,5].

Conclusion

Liquid biopsies represent a transformative shift in oncology, offering a non-invasive, real-time, and highly informative window into tumor biology. By capturing circulating tumor-derived signals, liquid biopsies can enable earlier cancer detection, precise monitoring of treatment response, identification of resistance mechanisms, and timely detection of minimal residual disease. Their advantages in patient comfort, repeatability, and systemic tumor representation position them as a powerful alternative and complement to traditional diagnostic approaches. While technical, biological, and economic challenges remain, the rapid pace of innovation in sequencing technologies, bioinformatics, and biomarker discovery is steadily addressing these barriers. In the coming decade, liquid biopsy has the potential to move from a promising adjunct to a new clinical standard in cancer screening and surveillance, fundamentally reshaping the landscape of cancer diagnosis and management. Its integration into routine practice not only aligns with the vision of personalized medicine but also heralds a future where cancer control is more proactive, precise, and patient-centered.

Acknowledgement

None.

Conflict of Interest

None.

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