Acta Scientific CNCER BIOLOGY (ISSN: 2582-4473)

Volume 10 Issue 2 February 2026

Editorial

Advances in Liquid Biopsy and Circulating Tumor DNA: A New Era in Cancer Detection and Monitoring

Hsiang-Yin Hsueh*

Department of Cell and Molecular Biology, The Ohio State University, United States of America

***Corresponding Author:** Hsiang-Yin Hsueh, Department of Cell and Molecular Biology, The Ohio State University, United States of America.

Received: October 28, 2025

Published: February 01, 2026

Abstract

Cancer biology has entered an era where disease monitoring is no longer restrained to invasive tissue biopsies. The detection of tumor-derived materials in blood and other body fluids is reshaping how we understand, detect, and treat cancer. Among its components, circulating tumor DNA (ctDNA) stands out as a minimally invasive window into the evolving genetic and epigenetic landscape of tumors. This editorial reflects on recent advances, ongoing challenges, and future directions in leveraging ctDNA to reshape our biological and clinical understanding of cancer.

Keywords: Liquid Biopsy; Circulating Tumor DNA; Cancer Biology; Tumor Heterogeneity; Early Detection; Precision Oncology

Introduction

Traditional cancer diagnostics rely heavily on tissue biopsies. While it is very informative, it only capture a snapshot of an inherently dynamic disease. Tumor heterogeneity, clonal evolution, and therapy-induced adaptations mean that the biology of cancer is constantly shifting. Liquid biopsy, a revolutionary approach that detects tumor-derived fragments such as circulating tumor DNA (ctDNA), circulating tumor cells (CTCs), and extracellular vesicles, has emerged as a tool that captures this fluidity in real time [1].

The use of ctDNA in particular has redefined cancer monitoring. Serial, non-invasive ctDNA analyses allow quantitative assessment of tumor burden, detection of minimal residual disease, and identification of resistance mutations, providing a molecular window into the real-time evolution of cancer.

Advances in cancer biology through ctDNA

At the core of ctDNA's promise lies its biological representativeness. Tumor cells release fragmented DNA into circulation through apoptosis, necrosis, and active secretion. These fragments carry the genetic and epigenetic signatures of the parent tumor, including point mutations, copy number changes, methylation patterns, and chromatin accessibility features. This has made ctDNA a versatile biomarker across multiple cancer types [2].

Clinically, ctDNA has already proven benefit in clinics. Studies have shown that ctDNA can detect cancer recurrence before imaging [3]. In metastatic settings, ctDNA profiling allows real-time identification of therapy-resistant clones and leads to treatment modifications more precisely than tissue biopsies [4]. These applications reveal how tumor evolution, selection pressures, and microenvironmental interactions shape cancer developments [2].

Furthermore, liquid biopsies are advancing our understanding of tumor heterogeneity. By analyzing ctDNA fragments over time, researchers can trace the rise and fall of distinct subclones, revealing the evolutionary forces that drive resistance and metastasis [5]. This dynamic view offers insights into cancer biology that solid tissue biopsies analysis cannot provide.

Challenges and limitations

Despite their potential, liquid biopsies face biological and technical challenges. The amount of ctDNA in circulation can be extremely low in early-stage cancers. Moreover, not all tumors release DNA into the bloodstream equally. The shedding rates vary with tumor type, size, vascularization, and metastatic site [6].

Technologically, while sequencing sensitivity continues to improve, there is a pressing need for standardization in pre-analytical processing, assay design, and data interpretation. These challenges underscore that liquid biopsy results is not a replacement for tumor biology but a complement that must be integrated with mechanistic understanding [7].

Future directions

The next phase of ctDNA research will center on coupling molecular detection with biological context. Integrating ctDNA profiles with transcriptomic, proteomic, and immune data will deepen our understanding of how genomic alterations translate into phenotypic behaviors. Understanding the kinetics of how stress, hypoxia, or immune attack modulate DNA release may reveal new biomarkers of tumor state and treatment response.

Artificial intelligence and machine learning are poised to accelerate this integration, correlating complex ctDNA patterns with biological and clinical outcomes. Ultimately, the convergence of liquid biopsy technology with foundational cancer biology will enable a more predictive, adaptive, and personalized approach to oncology.

Conclusion

In conclusion, liquid biopsy, particularly ctDNA analysis, showcases how technological innovation and biological insight can converge to reshape cancer care. This minimally invasive approach enables real-time monitoring of tumor evolution, treatment response, and disease persistence. However, to fully realize the promise of liquid biopsy, researchers must continue to use this tool to investigate the underlying mechanisms of cancer.

Bibliography

1. Ma L., *et al*. "Liquid biopsy in cancer current: status, challenges and future prospects". *Signal Transduction and Targeted Therapy* 9.1 (2024): 336.
2. Lone SN., *et al*. "Liquid biopsy: a step closer to transform diagnosis, prognosis and future of cancer treatments". *Molecular Cancer* 21.1 (2022): 79.
3. Ji J., *et al*. "Circulating Tumor DNA Testing in Curatively Resected Colorectal Cancer and Salvage Resection". *JAMA Network Open* 7.12 (2024): e2452661.
4. Bayle A., *et al*. "Liquid versus tissue biopsy for detecting actionable alterations according to the ESMO Scale for Clinical Actionability of molecular Targets in patients with advanced cancer: a study from the French National Center for Precision Medicine (PRISM)". *Annals of Oncology* 33.12 (2022): 1328-1331.
5. Sivapalan L., *et al*. "Liquid biopsy approaches to capture tumor evolution and clinical outcomes during cancer immunotherapy". *Journal of Immunotherapy Cancer* 11.1 (2023): e005924.
6. Stejskal P., *et al*. "Circulating tumor nucleic acids: biology, release mechanisms, and clinical relevance". *Molecular Cancer* 22.1 (2023): 15.
7. Desai A and Lovly CM. "Challenges in the implementation of ultrasensitive liquid biopsy approaches in precision oncology". *Journal of Immunotherapy Cancer* 11.6 (2023): e006793.