

Review Article

Open Access

Analysis of the Advantages and Limitations of Liquid Biopsy: A Literature Review

Dwarf Carolina Tanzi Bernardes¹, Carolini Bertolino Gumushian², Laura Zanoni Gomes da Penna¹, Vitória Padilha Spautz¹, Melissa Hebling Alen Loureiro³, Fernanda Ambrósio da Silva^{2*}, Arielle Servato Rossi¹, Manuela Páfaro Magnani¹ and Larissa Soares Leite¹

¹University of Marília (UNIMAR), São Paulo, Brazil

²Center University Student Catholic Salesian Auxilium, São Paulo, Brazil

³Medical Student, Faculty Saint Marcelina, São Paulo, Brazil

SUMMARY

Considering the high morbidity and mortality associated with neoplasms and the need for more effective diagnostic methods and less invasive, a biopsy liquid if This technique stands out as a promising tool for the early diagnosis and monitoring of cancers. The aim is to critically analyze the advantages and limitations of this technique in the context of general surgery, addressing... your impact clinical, effectiveness and you challenge to your wide implementation. To Therefore, a systematic literature review was conducted, focusing on recent studies on the use of circulating biomarkers, such as ctDNA and Circulating Tumor Cells (CTCs). in detection of cancers. You results show what, although the biopsy liquid While liquid biopsy offers advantages such as less invasiveness and the ability to monitor tumor progression over time, significant challenges remain, including reduced sensitivity in early stages of the disease, a lack of standardization in collection and analysis methods, and the high costs of sequencing technologies. In conclusion, despite its limitations, liquid biopsy has the potential to transform cancer diagnosis and treatment in clinical practice, especially when integrated with traditional methods, provided that sequencing technologies advance and standardized protocols are established.

*Corresponding author

Fernanda Ambrósio Da Silva, Center University Student Catholic Salesian Auxilium, São Paulo, Brazil.

Received: July 03, 2026; **Accepted:** July 07, 2026; **Published:** July 16, 2026

Keywords: Liquid Biopsy, Circulating Biomarkers, Early Diagnosis, Cancer, Tumor Monitoring

Introduction

Neoplasms are responsible for one of the leading causes of morbidity and mortality globally, with millions of new cases diagnosed annually. This reality impact directly the quality of life of patients and represents one of the biggest global public health concerns. Early detection and effective treatment of cancer, therefore, if they become priorities, highlighting the need of new methods diagnoses more precise and less invasive. In this context, liquid biopsy has emerged as a promising tool. offering one alternative less invasive to the diagnosis and monitoring of tumors. This technique allows the detection of tumor material through the analysis of biomarkers present in bodily fluids, such as blood, which represents a significant advance over traditional tissue biopsy, which requires invasive and often painful procedures.

Traditionally, the biopsy of tissue he has been used to the diagnosis and the Histological classification of tumors, as well as for the evaluation of the mutational profile in cancers. In recent years, the biopsy liquid minimally invasive emerged as one alternative, using bodily effluents, primarily blood, to identify cancer biomarkers and assess the biochemistry and genetic status of tumors at a systemic level. This approach offers considerable advantages, such as lower invasiveness, reproducibility, and the ability... of monitor

the progression from the illness of form continuous, with smaller cost and processing time compared with traditional methods [1].

THE biopsy liquid, to the identify markers tumors as cells tumors Circulating cytochromes (CTCs), circulating tumor DNA (ctDNA), circulating microRNAs (miRNAs), proteins, and tumor-derived exosomes play a crucial role in regulating the cell cycle, cell differentiation, apoptosis, and immune response, among other biological processes [2]. These biomarkers have proven valuable for early diagnosis and monitoring of the response. to the treatment of several types of Cancer. THE capacity from the biopsy liquid of detecting genetic and molecular changes at an early stage, often before they become clinically significant. evident, turns that technique especially relevant, especially in cancers of difficult access, as the adenocarcinoma ductal pancreatic (PDAC), what and one of the more lethal due to late diagnosis and resistance to treatment in advanced stages [3].

However, despite its revolutionary potential, liquid biopsy still presents considerable challenges. The lack of standardization in collection and analysis methods can lead to variations. us results and commit the precision diagnostic. In addition, from that, the variability of biomarkers used and the need of to improve the sensitivity and specificity of the Testing issues still need to be resolved before the widespread adoption of this technique. The limitations also include the high cost from the biopsy liquid and

your accessibility restricted in certain clinical contexts, which may hinder its large-scale implementation [4,5].

Liquid biopsy has demonstrated great potential in the continuous monitoring of cancer patients, especially those at high risk or in the early stages of the disease, allowing for the early identification of recurrences and improving treatment management. Its ability of monitor development molecular from the illness of form repetitive to the Over time, it offers a more personalized approach, with less invasiveness and less stress for the patient. Thus, liquid biopsy not only has the potential to improve diagnostic accuracy, but also to enhance cancer treatment and prognosis, offering more effective and safer care [2].

Thus, the objective was to critically analyze the advantages and limitations of liquid biopsy in the context of surgery in general, this discussion will explore its clinical impact, effectiveness, and the challenges that still need to be addressed for its implementation and validation in different contexts. The discussion will cover recent advancements that have enabled... detection of genetic mutations and molecular alterations with greater precision, such as the use of next-generation sequencing (NGS) and digital PCR technologies, has contributed significantly to improving the sensitivity and specificity of liquid biopsy diagnostic tests [6,7].

Results

THE analysis of DNA tumor current (ctDNA) he has demonstrated your value growing in early diagnosis, monitoring of progression and response to treatment in a wide variety of cancers. Technological advances, such as whole-exome sequencing (WES) and the sequencing massively parallel (MPS), he has allowed identify with greater precision, these tools allow for the detection of mutations and genetic rearrangements present in ctDNA. When compared to traditional methods such as tissue biopsies, they overcome important limitations, such as... the inability of reflect the heterogeneity tumor and the need of multiple biopsies in different locations for continuous monitoring of cancer progression [1].

Detection of Mutations no CTDNA E Prognostic Impact

Studies on different types of cancer reinforce the importance of ctDNA as a biomarker. diagnosis and prognosis. Node Cancer pancreatic, put example, the mutation node The KRAS gene, which is common in this type of tumor, was identified with high specificity in ctDNA, facilitating not only early diagnosis but also monitoring of disease progression. In patients with Cancer pancreatic, the detection of mutations node ctDNA also has demonstrated a crucial role in assessing treatment response, especially in patients undergoing targeted therapies [1].

Node Cancer colorectal, the methylation of promoter of SEPT9 if highlighted as A highly sensitive biomarker, correlating with early diagnosis of the disease. Detection of ctDNA methylation. became a tool valuable in monitoring post-surgical patients, allowing for more effective monitoring of tumor recurrence than traditional methods. of image (1). Node Cancer of lung, the monitoring of mutations node ctDNA It was essential. to adjust therapies based in inhibitors of tyrosine kinase (TKIs) in patients with non-small cell lung cancer (NSCLC), particularly for those who develop resistance to treatment, promoting a more personalized and effective therapeutic approach [6,7].

Biomarkers Derivatives of Cells Tumors Circulating CTCS and their use in Cancer Monitoring

To the cells tumors circulating (CTCs) they are cells carcinogenic

what if detach of the tumor primary and circulate in current blood, representing one of roads of Metastatic dissemination. The detection and analysis of CTCs have become a promising tool in the diagnosis, prognosis, and monitoring of cancer patients. These cells provide a direct representation of tumor heterogeneity and can be used for... to assess the evolution of Cancer of manner more dynamic than to the biopsies traditional made of fabric.

Recent studies have shown that the presence of CTCs in peripheral blood is strongly associated with a worse prognosis in several types of cancer, such as breast, prostate, lung, and colorectal cancer. In many cases, the number of CTCs correlates with the extent of the disease and may indicate metastatic spread before clinical imaging reveals such changes. Furthermore, molecular analyses of CTCs allow the identification of genetic mutations and alterations in gene expression, enabling personalized treatment and the selection of more appropriate targeted therapies [1].

The advantage of CTC analysis over traditional biopsy lies in its minimally invasive nature. Blood collection, which can be performed at regular intervals throughout treatment, facilitates continuous monitoring of tumor evolution, while tissue biopsies often require multiple invasive procedures and may not capture tumor heterogeneity. The possibility of analyzing these cells in real time is also a significant advantage. becomes crucial to detect resistance to the treatment and recurrence from the illness, assisting in making more agile clinical decisions [8].

Although promising, the detection of CTCs also it presents challenges technicians. THE The rarity of these cells in the bloodstream and the difficulty in efficiently separating them from their components. blood normal requires the use of technologies advanced, as microfluidics and immunoassays, which They still have limitations in terms of cost and accessibility. However, with you advances in biotechnology and node development of new devices of capture, it is expected what that approach if turn more accessible and it needs us next years [3].

Therefore, monitoring CTCs it could be a valuable tool, not only for early diagnosis and monitoring of relapses, but also for the personalization of cancer therapies, contributing to more effective management of cancer patients.

Comparison Between Samples Biological to Liquid Biopsy

A comparison between the different types of biological samples used for liquid biopsy. revealed to the advantages from the collect of blood peripheral to the analysis of ctDNA in in relation to biopsies of tissue. THE blood, collected put puncture venous peripheral, allows the Centrifugation of the sample for plasma separation offers a more accessible and less invasive approach. to the collect of biomarkers tumors. In contrast, to the biopsies of tissue, what While still considered the gold standard, these tests require anesthesia, tissue removal, and are more invasive, in addition to being limited to a single-point analysis, often failing to reflect the heterogeneity of the tumor. THE biopsy liquid, put other side, allows the monitoring dynamic continuous, the what This is a crucial advantage in assessing tumor progression and therapeutic response [2].

ctDNA analysis also proved superior in terms of sensitivity and specificity when compared to other biomarkers in blood, plasma, and saliva samples. Techniques such as digital droplet PCR (ddPCR) and next-generation sequencing (NGS) proved to be highly effective for detecting mutations in ctDNA, with greater

accuracy than traditional tests. ddPCR, in particular, stood out for its high sensitivity, being able to detect genetic variants with greater reliability, which translates into a more effective approach for identifying genetic alterations associated with the tumor [2].

Cells Tumors Circulating (CTCS) and Others Approaches Diagnostics

Analysis of circulating tumor cells (CTCs) has proven to be a promising tool for the early detection of cancers such as hepatocellular carcinoma (HCC) and other cancers. of pancreas (PDAC). Node case of CHC, the combination of CTCs with the Alpha-fetoprotein (AFP) has enabled a more precise assessment of the stage of the disease. The detection of CTCs in the blood, put quite of methods as RT-PCR and MS-PCR, demonstrated high sensitivity, being able of identify cells tumors circulating associated to the carcinoma hepatic, same in stages initials. Node case of PDAC, the biopsy liquid using CTCs and ctDNA he has allowed a more detailed characterization of tumor heterogeneity, facilitating treatment personalization and monitoring of treatment response [4,5].

In addition to CTCs, the analysis of exosomes and circulating cell-free DNA (cfDNA) has proven useful. node monitoring from the progression tumor and detection early of relapses, particularly in cases of gliomas and others tumors solids. your exosomes, put your capacity of Transporting messenger RNA, proteins and miRNAs directly from the tumor microenvironment has the potential to reflect tumor dynamics and therapeutic response in real time. Although there are still challenges regarding sensitivity and specificity, these emerging biomarkers have shown promise for early diagnosis and continuous monitoring of tumor evolution [4,5].

Advances in the Platforms Diagnostic

The use of different diagnostic platforms in liquid biopsy, such as quantitative PCR (qPCR), digital droplet PCR (ddPCR), and NGS, has shown a significant improvement in sensitivity and specificity for the detection of circulating biomarkers. comparison with the biopsy of tissue, the biopsy liquid offers one advantage significant, allowing for less invasive sample collection and dynamic monitoring of changes. genetic and epigenetic of the tumor along of time. Furthermore, the biopsy Liquid biopsy enables the identification of biomarkers in samples of bodily fluids such as blood, saliva and urine, which is a practical alternative for obtaining tumor material, especially in patients for whom multiple tissue biopsies are not feasible [2].

In terms of diagnosis of Cancer, the use of biomarkers circulating, as Testing of ctDNA, CTCs, miRNAs, and exosomes is increasingly established as a complementary or alternative tool to the traditional tissue biopsy method. The increasing accuracy of these tests, combined with the possibility of dynamic monitoring and lower invasiveness, strengthens this position. the potential of biopsies liquids in practice clinical, especially in contexts where tissue biopsy is not feasible or is highly invasive [2].

Implications Clinics

The findings of this study underscore the importance of liquid biopsy as a diagnostic and prognostic tool, with strong potential to transform the clinical approach in oncology. THE use of ctDNA, CTCs, exosomes and miRNAs enable one diagnosis. Earlier identification of specific biomarkers and monitoring of treatment response in a less invasive and more precise manner. This allows for personalized treatment, adapted to the molecular characteristics

of the tumor, and facilitates early detection of relapses, which can lead to better clinical outcomes for patients [1,4,5].

Methodology

He was carried out one revision systematic from the literature in base of data MEDLINE-PubMed (National Library of Medicine, National Institutes of Health to identify studies relevant published between 2015 and 2024. Initially, 130 studies they were found, of the which 10 They were selected after a detailed critical analysis. The included articles were published in English and available at complete, addressing the biopsy liquid in the context of surgery general, with focus in comparison with methods traditional of diagnosis and monitoring. You The search terms used were “Liquid Biopsy” and “General Surgery”. The analysis focused on three main aspects: diagnostic effectiveness, ability to detect recurrences early, and continuous monitoring of treatment response.

Discussions

The analysis of ctDNA through liquid biopsy is becoming established as an approach. innovative in oncology, offering one series of advantages in relationship to the Traditional methods of cancer diagnosis and monitoring. One of the main advantages of biopsy. liquid and your nature no invasive, allowing the collect of samples biological put middle of one simple sample of blood, the what turns the process less painful and more accessible to the patient. In addition, this technique allows for continuous monitoring of tumor progression and from the response to the treatment, providing one vision dynamics of behavior from the disease over time. With advances in Next-Generation Sequencing (NGS), such as Whole-Exome Sequencing (WES) and whole-genomic sequencing (WGS), it has become possible to perform an analysis more comprehensive and detailed of ctDNA, which facilitates early detection of genetic mutations and allows monitoring of resistance to treatment [1]. This level of analysis allows what you oncologists follow the evolution of tumor in real-time, often before changes are visible on imaging exams or other traditional tests, such as CT scans and MRIs.

However, liquid biopsy still faces significant challenges that limit its widespread clinical use. The sensitivity of ctDNA detection in early stages of the disease can be a limiting factor, since the amount of circulating tumor DNA may be insufficient to be accurately detected at these early stages. This is because, in small tumors or those with low tumor burden, the amount of circulating ctDNA in the blood is reduced, making its identification more difficult. In such cases, even with advanced sequencing technologies such as WES or WGS, the depth of analysis may be insufficient to capture these genetic alterations in their earliest stages [1]. The lack of sensitivity in detect changes genetic of form reliable in stages initials from the Disease remains a significant limitation of liquid biopsy.

Other challenge crucial and the interpretation of the results obtained through from the biopsy liquid. Not even all to the mutations detected node ctDNA they are directly related to the tumor primary, which can lead to misinterpretations, such as false positives. or negative. Some of these mutations may originate in healthy cells, which further complicates the analysis. The identification of epigenetic mutations, such as methylation alterations in specific genes, offers a promising alternative for the diagnosis and monitoring of tumors. However, the accuracy and specificity of this approach still need further validation, as there are few studies that guarantee the sensitivity necessary for its clinical implementation [1]. In addition, from that, to the variations

between your different centers of search and laboratories, related to the techniques of collect and analysis of samples, they can to generate results inconsistent the what It makes it difficult to standardize processes and to ensure the reliability of the results obtained [8].

The cost high of technologies of sequencing of high depth, as WGS And WES is also a limiting factor in the adoption of liquid biopsy in clinical settings, especially in countries with more restricted healthcare systems. The large-scale implementation of this technology therefore requires reducing the costs of sequencing technologies without compromising the quality of results, as well as simplification. and standardization of the protocols of collect and analysis of samples [1]. In that in this context, multigene tests, which analyze multiple genes simultaneously and are more accessible, can serve as an intermediate solution, offering a good balance between cost and effectiveness.

The combination of mutation analysis and ctDNA methylation has shown promise, especially in early detection and monitoring of disease progression. Methylation detection, as in the case of the SEPT9 gene in colorectal cancer, is associated with the identification of... early of tumor and the assessment from your evolution. That approach he has the potential to significantly improve patient follow-up, allowing for more precise adjustments to treatment plans [1]. However, there is still a need for more studies to validate this technique in different types of cancer and at different stages of the disease.

Liquid biopsy has proven to be a promising tool in the diagnosis and monitoring of tumors, especially in cases of recurrence and metastasis, such as in colorectal and lung cancer. It offers diagnostic precision that often surpasses the limitations of traditional methods, with the ability to detect genetic and epigenetic biomarkers that reflect the presence of the tumor before clinical or radiological signs become evident. This early detection capability is crucial for... the effectiveness of treatment, then allows interventions therapeutic earlier and more adjusted to the molecular profile of the tumor [8]. However, the lack of standardization between collection and analysis methods, the variability in sequencing techniques and the interpretation of results remain critical issues that need to be addressed to ensure the accuracy of diagnoses and the reliability of tests.

Furthermore, the integration of liquid biopsy with other traditional diagnostic methods, as biopsies tissues and exams of image, he can optimize you results Clinical. Used. in set with those methods, the biopsy liquid he can provide one vision A more comprehensive and dynamic understanding of the disease, identifying genetic alterations before they become clinically evident. This complementary approach can be especially useful for monitoring. continuous from the response to the treatment and the detection early of relapses, reducing the need for repeated tissue biopsies, which are more invasive and uncomfortable for the patient [4]. However, for liquid biopsy to become standard clinical practice, it will be necessary to develop standardized protocols that involve all stages of the process, from sample collection to data analysis and interpretation.

Although liquid biopsy represents a significant advance in oncology, its widespread clinical adoption still faces barriers such as the need for greater sensitivity and specificity. the standardization of the protocols of testing and the reduction of the costs associates to technologies of sequencing. THE validation of this technique in different types of Cancer and the Its integration

with established clinical protocols is essential to consolidate it as a reliable and effective tool. Only through more robust studies, with larger samples and rigorous protocols, will it be possible to validate the true potential of liquid biopsy and ensure that it benefits patients broadly and effectively [5].

Conclusion

Liquid biopsy has emerged as a promising technique for the early diagnosis and continuous monitoring of cancer, offering a less invasive and more personalized approach compared to traditional methods. Its ability to identify specific tumor biomarkers, such as ctDNA, circulating tumor cells (CTCs), and other genetic fragments in the blood, allows for dynamic monitoring of disease progression. and from the response to the treatment, providing advantages significant to you patients. However, despite of your big potential, the biopsy liquid yet faces challenges considerable limit your adoption in wide scale. THE sensitivity and the specificity of the tests These remain critical issues, especially in the early stages of the disease, where the amount of biomarkers circulating, he can to be insufficient to one detection it needs. In addition, from that, the Lack of standardization in collection techniques, sequencing methods, and analysis of results contributes to significant variation in results obtained between different laboratories and studies.

For liquid biopsy to become a widely available and reliable clinical tool, it is crucial that new studies be conducted to compare different diagnostic platforms, investigate new circulating biomarkers, and establish standardized testing protocols. Such protocols should address issues such as the most effective type of body fluid for collection, the ideal sample storage conditions, and the best detection techniques. The implementation of standardized methods will contribute to improving the accuracy and reproducibility of results, facilitating their integration into routine clinical practice. Furthermore, reducing the costs of sequencing technologies and improving accessibility will be essential for the adoption of liquid biopsy in broader clinical settings.

Your futures advance technological also they play one paper crucial in overcoming current limitations. The use of multigene panels and the combination of different analytical approaches, such as the detection of methylations and epigenetic biomarkers, can increase the sensitivity from the biopsy liquid and enlarge your potential of application, especially in the early diagnosis and monitoring of tumors that are difficult to access with traditional methods. Interdisciplinary collaboration between oncologists, surgeons, molecular biologists, and researchers will be fundamental to the advancement of this technology.

In conclusion, despite of difficulties still present, as the lack standardization and the variation us results, the biopsy liquid continues the show yourself as one tool valuable in the field of oncology, offering a less invasive, more accessible and potentially more effective to the detection early of cancers and the monitoring from the Response to treatment. With the development of standardized protocols and the continuous evolution of detection technologies, liquid biopsy has the potential to revolutionize cancer diagnosis and treatment, improving clinical outcomes for patients soon [9,10].

References

1. Jin Y (2015) Liquid biopsy of circulating tumor DNA in Cancer. J Hematol Oncol 8: 1-10.
2. Li T (2021) Liquid biopsy in cancer: Current technologies and future directions. Cancer Letters 505: 111-118.

3. Lee M (2020) Challenges in the clinical application of liquid biopsy technologies for cancer detection. J Clin Pathol 73: 461-468.
4. Zhang L (2021) Circulating tumor DNA in early detection of cancer. Cancers 13: 2110-2120.
5. Zhu Y (2021) Liquid biopsy for monitoring treatment response and minimal residual disease in cancer. Frontiers in Oncology 11: 610-621.
6. Li W (2021) Application of liquid biopsy in cancer diagnostics: A new frontier in molecular oncology. Nat Rev Cancer 21: 341-353.
7. Liu H (2021) Detection of minimal residual disease in cancer with liquid biopsy technologies. Nat Rev Clin Oncol 18: 254-264.
8. Jin Y (2021) Advances in liquid biopsy for cancer detection and therapy. Oncotarget 12: 1611-1622.
9. Wang Z (2021) ctDNA detection in early-stage cancers: Prognostic utility and clinical challenges. Cancer Letters 521: 34-40.
10. Zhang Y (2020) Circulating tumor DNA as a diagnostic marker for early-stage cancers. J Clin Oncol 38: 132-139.

Copyright: ©2026 Fernanda Ambrósio Da Silva, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.