

EARLY CANCER DETECTION USING BIOPHYSICAL METHODS: BASED ON AMERICAN EXPERIENCE

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Annotation: Early detection of cancer is one of the most promising strategies to decrease mortality and improve the effectiveness of treatment. The American experience in this field demonstrates the crucial role of biophysical methods in identifying oncological diseases at their earliest stages. Biophysical diagnostic tools, including magnetic resonance imaging (MRI), computed tomography (CT), positron emission tomography (PET), optical coherence tomography (OCT), and ultrasound elastography, allow non-invasive assessment of tissue structure, metabolism, and elasticity, revealing abnormalities long before clinical symptoms appear. In the United States, the combination of these imaging techniques with molecular diagnostics and artificial intelligence systems has greatly improved diagnostic precision and patient outcomes. Recent innovations such as nanoplasmonic sensors, quantum dots, and biosensors enable highly sensitive detection of cancer biomarkers in blood, forming the foundation for liquid biopsy technologies. This integration of biophysical and digital methods supports real-time tumor monitoring and personalized medicine approaches. The American model highlights the importance of preventive screening programs such as mammography and low-dose CT scans—supported by advanced imaging and data analysis. As a result, early detection rates and survival outcomes have markedly improved across various cancer types. Overall, biophysical methods represent a vital component of modern oncology, ensuring timely diagnosis, accurate treatment planning, and a higher quality of life for patients.

Keywords: biophysical methods; early cancer detection; American experience; medical imaging; magnetic resonance imaging (MRI); computed tomography (CT); positron emission tomography (PET); optical coherence tomography (OCT); ultrasound elastography; nanobiophysics; biosensors; liquid biopsy; artificial intelligence (AI); molecular diagnostics; preventive screening.

Statistical Overview: Early Cancer Detection in the United States

According to national research institutions, early cancer detection remains one of the most effective strategies to reduce mortality and healthcare costs in the United States. However, despite extensive screening programs, many cancers are still diagnosed at advanced stages, emphasizing the need for more sensitive biophysical and molecular diagnostic tools.

1. General Screening Coverage

According to NORC at the University of Chicago, only about 14 % of all cancer cases in the U.S. are detected through recommended screening programs. This means that nearly 86 % of cancer diagnoses occur after symptoms appear or through unrelated medical examinations. Existing screening tools primarily cover breast, cervical, colorectal, and lung cancers, leaving many other cancer types undetected until late stages.

2. Screening Participation Rates (2023–2025)

- Breast cancer screening: Approximately 79.8 % of women aged 50–74 reported having a mammogram within the past two years.

- Cervical cancer screening: Around 75.4 % of eligible women were screened within recommended intervals.



- Colorectal cancer screening: The overall participation rate was 67.4 %, while among adults aged 45–49 it was only 37.1 %.
- Lung cancer screening: Despite high mortality, only about 3 % of lung cancer cases are detected through early screening programs.

3. Economic and Clinical Impact

A large-scale study by the University of Michigan's Institute for Healthcare Policy and Innovation (IHPI) estimated that early cancer screening in the U.S. over the past 25 years has saved more than 12 million life-years, with an approximate economic value of \$6.5 trillion. These findings highlight that early detection is not only clinically beneficial but also economically vital for healthcare systems.

4. Technological Integration and Biophysical Advances

The United States has increasingly incorporated biophysical diagnostic methods—such as MRI, PET/CT, ultrasound elastography, and optical imaging—into early screening protocols. Combined with artificial intelligence (AI) and molecular diagnostics, these tools have significantly improved accuracy, reducing false negatives and enabling real-time tumor monitoring.

Analytical Insight

Despite high technological capacity, U.S. statistics show that early detection programs still miss a substantial proportion of cancers. This gap underscores the need to further develop biophysical and nanotechnological diagnostic platforms, including biosensors, liquid biopsies, and hybrid imaging systems, to identify cancer at the molecular and cellular level before symptoms appear.

Methods

This study is based on a comprehensive analytical review of the biophysical approaches applied in early cancer detection in the United States. The methodological framework combines data analysis from official American health databases, scientific publications, and clinical research programs implemented between 2015 and 2025. The focus was on evaluating the diagnostic accuracy, sensitivity, and predictive value of major biophysical methods used in oncology.

Data Sources and Selection Criteria

Statistical data were obtained from the Centers for Disease Control and Prevention (CDC), National Cancer Institute (NCI), American Cancer Society (ACS), and peer-reviewed journals indexed in PubMed and ScienceDirect. Only studies that evaluated non-invasive or minimally invasive diagnostic technologies for early cancer detection were included. The analysis covered population-based screening programs and experimental studies involving imaging, spectroscopy, and biosensor applications.

2. Biophysical Imaging Methods

The study examined the role of advanced imaging techniques widely used in American medical centers:

- Magnetic Resonance Imaging (MRI): Applied for high-resolution visualization of soft tissues, brain, and breast tumors, focusing on diffusion and perfusion imaging.



- Computed Tomography (CT): Used for structural assessment of lung, liver, and pancreatic cancers with enhanced contrast resolution.
- Positron Emission Tomography (PET) and PET/CT: Combined anatomical and metabolic imaging for tumor localization and evaluation of early-stage metabolic changes.
- Optical Coherence Tomography (OCT): Used for real-time microstructural imaging of epithelial tissues, including cervical and oral mucosa.
- Ultrasound Elastography: Evaluated for tissue stiffness measurement and differentiation between malignant and benign lesions.

3. *Nanobiophysical and Biosensor Technologies*

Modern American laboratories were reviewed for their use of nanoplasmonic sensors, quantum dots, and electrochemical biosensors in detecting tumor biomarkers such as circulating tumor DNA (ctDNA), exosomes, and specific proteins. The performance of liquid biopsy platforms was analyzed for their diagnostic sensitivity and specificity in comparison with conventional imaging methods.

4. *Integration of Artificial Intelligence (AI)*

A separate methodological focus was placed on the integration of machine learning algorithms and AI-based image analysis systems that process large datasets from MRI, CT, and PET images. Deep learning models trained on annotated datasets were evaluated for their ability to identify early morphological and metabolic abnormalities invisible to the human eye.

5. *Analytical and Comparative Evaluation*

The efficiency of biophysical methods was compared using parameters such as diagnostic accuracy, false-positive and false-negative rates, and cost-effectiveness. Comparative analysis was conducted against traditional screening tests (mammography, colonoscopy, and cytological analysis) to assess the advantages of advanced biophysical technologies in early detection and patient monitoring.

Conclusion

The analysis of the American experience clearly shows that the application of biophysical methods plays a central role in improving the early detection of cancer. The integration of advanced imaging technologies such as MRI, CT, PET/CT, OCT, and ultrasound elastography has allowed physicians to identify malignant changes at their earliest stages, often before the appearance of clinical symptoms. This has led to a measurable improvement in diagnostic accuracy, treatment effectiveness, and overall patient survival. Statistical data from U.S. health agencies demonstrate both achievements and challenges. Despite technological progress, only about 14% of cancers are currently diagnosed through recommended screening programs. Participation rates vary—approximately 80% for breast cancer, 75% for cervical cancer, and 67% for colorectal cancer—while lung cancer screening remains critically low at about 3%. These figures emphasize the continuing need for more sensitive and widely accessible diagnostic systems. The introduction of nanobiophysical and biosensor-based methods, such as liquid biopsy and nanoplasmonic sensors, has further expanded diagnostic potential by enabling non-invasive detection of tumor biomarkers in biological fluids. At the same time, the incorporation of artificial intelligence (AI) and machine learning into image analysis has significantly increased the precision of early diagnostics, reducing false results and enhancing clinical decision-making. Overall, the American model illustrates that early cancer detection can be greatly improved through the combined use of biophysical technologies, digital analysis, and preventive screening programs. Continued investment in these innovations—along with



public education and global accessibility—can ensure earlier diagnosis, lower mortality, and a higher quality of life for patients worldwide.

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