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Short Communication

Portable Biosensor Chips for Point-of-Care Cancer Diagnostics

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DESCRIPTION

Early detection of cancer is essential for improving patient outcomes and survival rates. Traditional laboratory based diagnostics, including histopathological examination and molecular assays, often require complex sample processing, specialized equipment, and prolonged turnaround times, which limit accessibility and timely clinical decision making. Portable biosensor chips represent a transformative approach for point-of-care cancer diagnostics by enabling rapid, sensitive, and minimally invasive detection of biomarkers at the patient bedside or in remote settings. These devices integrate microfabrication, nanotechnology, and bioengineering to detect molecular signatures of cancer directly from bodily fluids such as blood, urine, or saliva, offering a practical alternative to conventional laboratory testing [1].

Portable biosensor chips function by converting a biological interaction into a measurable electrical, optical, or mechanical signal. These devices typically incorporate a recognition element, such as antibodies, aptamers, or nucleic acid probes, which specifically bind to cancer associated biomarkers. Upon binding, the signal transduction component converts the biochemical event into a detectable output, which can be quantified using miniaturized readout systems [2]. Advances in microelectronics and microfluidics have enabled the development of compact, integrated platforms capable of multiplexed detection, high sensitivity, and real-time monitoring, making them highly suitable for point-of-care applications. In cancer diagnostics, biosensor chips target a range of biomarkers, including proteins, circulating nucleic acids, exosomes, and metabolites. Exosomes, which are nanoscale extracellular vesicles released by tumor cells, carry a repertoire of proteins, lipids, and nucleic acids reflective of tumor biology [3,4]. Detection of these biomarkers using portable biosensor chips allows clinicians to assess disease presence, stage, and therapeutic response with minimal invasiveness.

Microfluidic integration is a critical feature of portable biosensor chips. Microfluidic channels enable precise manipulation of small sample volumes, efficient mixing with reagents, and isolation of target biomarkers from complex biological matrices. This miniaturization reduces reagent consumption, enhances assay speed, and supports automated sample processing. In addition, surface modification techniques and nanostructured materials, such as gold nanoparticles, graphene, and carbon nanotubes, improve biomarker capture efficiency and signal amplification [5]. By combining microfluidics with nanomaterials, portable biosensor chips achieve sensitivity comparable to laboratory based assays while maintaining rapid analysis times suitable for point-of-care use.

The implementation of portable biosensor chips has been demonstrated in multiple cancer types, including breast cancer, lung cancer, colorectal cancer, and prostate cancer. Clinical studies have shown that these devices can detect biomarkers at picomolar to femtomolar concentrations, providing early indications of malignancy before conventional imaging or laboratory tests can identify tumors. Furthermore, the ability to perform longitudinal monitoring of biomarker levels enables real-time assessment of therapeutic response and early detection of relapse, supporting personalized treatment strategies [6].

Portability and user friendliness are key advantages of these devices. Portable biosensor chips are designed for use by clinicians, nurses, or even patients themselves, without extensive technical training. The readout can be interfaced with smartphones or dedicated handheld devices, allowing data visualization, storage, and remote transmission for telemedicine applications. This accessibility is particularly valuable in low resource or rural settings, where conventional laboratory infrastructure may be limited [7]. The integration of biosensor technology with digital platforms supports centralized data analysis, population level screening programs, and early detection initiatives, thereby enhancing cancer surveillance on a broader scale.

Future developments in portable biosensor technology are likely to focus on integrating artificial intelligence, machine learning, and predictive analytics to enhance diagnostic accuracy and interpret complex biomarker patterns. Advanced materials, such as stimuli responsive polymers and bioinspired nanostructures, may further improve sensitivity and selectivity [8-10]. Point-of-care biosensor chips may evolve into comprehensive platforms capable of simultaneous detection of cancer biomarkers, immune signatures, and metabolic indicators, providing a

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holistic view of disease state and progression. Such integrated approaches have the potential to transform cancer diagnostics from reactive, laboratory based testing to proactive, personalized monitoring and early intervention.

CONCLUSION

Portable biosensor chips represent a paradigm shift in cancer diagnostics, offering rapid, sensitive, and minimally invasive detection of disease biomarkers at the point of care. By combining microfluidics, nanomaterials, and bioengineering, these devices enable real-time assessment of tumor presence, progression, and therapeutic response. Clinical studies demonstrate their potential across multiple cancer types, and integration with digital platforms supports remote monitoring and personalized treatment strategies. While challenges remain in standardization, validation, and multiplexing, ongoing research and technological advances promise to expand the clinical impact of portable biosensor chips. Their widespread adoption could improve early detection, facilitate timely intervention, and ultimately enhance patient outcomes in oncology worldwide.

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