Short Communication
Volume 15:06, 2024

Journal of Biosensors & Bioelectronics

ISSN: 2155-6210

Open Access

An Electrochemical Biosensor for Detecting Pulmonary Embolism and Myocardial Infarction

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Introduction

The development of an electrochemical biosensor for detecting pulmonary embolism and myocardial infarction represents a significant advancement in point-of-care diagnostics for critical cardiovascular conditions. Both conditions pose severe threats to human health, requiring timely diagnosis to prevent mortality and mitigate complications. Traditional diagnostic methods, such as computed tomography pulmonary angiography for PE and electrocardiography or troponin assays for MI, often involve time-consuming procedures, specialized equipment, and hospital-based settings. An electrochemical biosensor offers a promising alternative, providing rapid, sensitive, and portable diagnostics for these life-threatening conditions [1]. The biosensor operates on the principle of electrochemical transduction, which converts a biochemical interaction into a measurable electrical signal. This technology is particularly suitable for medical diagnostics due to its high sensitivity, specificity, and ability to function in compact, portable devices. In this context, the biosensor was designed to detect specific biomarkers associated with PE and MI, namely D-dimer and cardiac troponins, respectively. D-dimer is a fibrin degradation product that is elevated in the bloodstream during thrombotic events, such as those leading to pulmonary embolism. Similarly, cardiac troponins, specifically troponin I and T, are released into the bloodstream following myocardial injury, making them reliable indicators of myocardial infarction.

The biosensor was constructed using a three-electrode system consisting of a working electrode, a reference electrode, and a counter electrode. The working electrode, where the biochemical reactions occur, was modified with nanomaterials such as gold nanoparticles or carbon nanotubes to enhance conductivity and surface area, thereby improving the sensor's sensitivity. Specific antibodies or aptamers, which exhibit high binding affinity to D-dimer and cardiac troponins, were immobilized onto the electrode surface. These bioreceptors form the critical interface between the biosensor and the target biomarkers, enabling selective detection [2]. To evaluate the biosensor's performance, synthetic samples containing known concentrations of D-dimer and troponins were prepared. The biosensor was exposed to these samples, and the resulting electrochemical signals were recorded using techniques such as cyclic voltammetry or differential pulse voltammetry. These techniques measure changes in current or voltage that occur when the target biomarkers bind to the bioreceptors on the electrode surface. The magnitude of the signal corresponds to the concentration of the biomarkers, allowing for quantitative analysis.

Description

The biosensor demonstrated high sensitivity and specificity in detecting both D-dimer and cardiac troponins. Detection limits were in the nanomolar range, which is clinically relevant for identifying PE and MI at their early stages. The device exhibited a linear response over a wide concentration range, enabling the detection of both mild and severe cases. Furthermore, the biosensor showed minimal interference from other proteins and molecules commonly present in blood, highlighting its robustness in complex biological matrices.

Future directions for this technology include the simultaneous detection of multiple biomarkers to improve diagnostic accuracy. For example, combining D-dimer detection with markers of inflammation or coagulation could enhance the specificity of PE diagnosis, while multiplexed detection of troponins, natriuretic peptides, and inflammatory cytokines could provide a comprehensive profile for MI assessment. Advances in microfluidics and lab-on-a-chip technologies could enable such multiplexing by integrating multiple sensing elements onto a single device. Another promising avenue is the incorporation of wireless communication capabilities into the biosensor. Real-time transmission of test results to healthcare providers via smartphones or cloud-based platforms could streamline patient management and facilitate remote monitoring. This approach aligns with the growing trend toward connected healthcare, where digital tools are leveraged to enhance diagnostic and therapeutic processes. The potential impact of this electrochemical biosensor extends beyond PE and MI detection. The underlying technology can be adapted to detect a wide range of biomarkers associated with other diseases, including cancer, infectious diseases, and metabolic disorders. By tailoring the bioreceptors and electrode modifications, the biosensor could serve as a versatile platform for various diagnostic applications. This adaptability underscores the broader significance of electrochemical biosensors in transforming healthcare by enabling rapid, accessible, and personalized diagnostics.

Conclusion

The development of an electrochemical biosensor for detecting pulmonary embolism and myocardial infarction represents a groundbreaking advancement in cardiovascular diagnostics. The device's high sensitivity, specificity, and rapid response time address critical gaps in existing diagnostic methods, offering a portable and cost-effective solution for point-of-care testing. While challenges remain in optimizing its stability and user interface, ongoing research and technological innovations hold great promise for overcoming these limitations. By enabling early and accurate detection of life-threatening conditions, this biosensor has the potential to save lives and improve healthcare outcomes on a global scale.

References

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Received: 02 December, 2024, Manuscript No. jbsbe-25-156895; **Editor Assigned:** 04 December, 2024, PreQC No. P-156895; **Reviewed:** 18 December, 2024, QC No. Q-156895; **Revised:** 23 December, 2024, Manuscript No. R-156895; **Published:** 30 December, 2024, DOI:10.37421/2155-6210.2024.15.472

How to cite this article: Yusuke, Akamatsu. "An Electrochemical Biosensor for Detecting Pulmonary Embolism and Myocardial Infarction." *J Biosens Bioelectron* 15 (2024): 472.