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Aptamer Biosensors: Rapid Heterogeneous Vancomycin-Intermediate *Staphylococcus aureus* Detection Solution

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ABSTRACT

Vancomycin is an essential glycopeptide antibiotic facing challenges from resistant bacterial strains such as vancomycin-intermediate *Staphylococcus aureus* (VISA) and heterogeneous VISA (hVISA). Timely and precise identification of these strains is vital for efficient infection control. This report explores using aptamer-based biosensors as a novel solution for the rapid detection of hVISA. Aptamers, short, single-stranded nucleic acids, exhibit remarkable specificity and strong affinity for their targets, making them outstanding candidates for biosensor creation. These biosensors offer affordability, ease of customization, and swift performance, making them highly appropriate for medical settings. By utilizing electrochemical detection techniques, aptamer-based biosensors facilitate real-time tracking of vancomycin concentrations and may also contribute to the efficient detection of hVISA, addressing urgent demands in infectious disease control.

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Introduction

Vancomycin, a powerful glycopeptide antibiotic, is a strong antibiotic that encounters resistance from an increasing variety of bacterial strains, often due to improper administration (1). As well, vancomycin is linked to a range of side effects, mainly affecting the ears and the kidneys, thus necessitating close therapeutic drug monitoring (2). *Staphylococcus aureus* strains with intermediate resistance to vancomycin (VISA) and their heterogeneous variants (hVISA) are linked to treatment failures and are emerging as a growing concern for public health (3). Furthermore, in hVISA strains, the vancomycin minimum inhibitory concentration (MIC) falls within the susceptible range when evaluated by conventional methods, yet a fraction of the bacterial population remains resistant to vancomycin (4). Timely and accurate detection of patients carrying VISA, hVISA, and vancomycin-resistant *Staphylococcus aureus* (VRSA), along with the swift implementation of infection-control measures, is crucial for preventing the spread and emergence of these strains (4).

Aptamers are short, single-stranded molecules of DNA, RNA, or synthetic XNA that can be engineered to exhibit strong affinity and specificity for interacting with specific targets (5). Aptamers, screened by systematic evolution of ligands via exponential enrichment (SELEX) (6). So far, thousands of aptamers have been discovered, capable of recognizing a variety of targets with strong affinity and specificity, including small metal ions, organic compounds, amino acids, proteins, bacteria, viruses, entire cells, and even organisms (7). Aptasensors, using aptamers as recognition elements, incorporate single-stranded DNA or RNA molecules, providing exceptional flexibility in detecting targets. Functioning similarly to immunosensors, aptasensors produce signals through the distinctive folding of aptamers when they bind to their targets, which are subsequently converted for detection (8). Recently, a novel class of biosensors has been introduced, capable of continuously monitoring biomolecules in vivo through electrochemical sensors utilizing highly sensitive and specific structure-switching aptamer probes (9, 10). Upon binding to its target, the aptamer experiences a reversible conformational shift, resulting in a change in faradaic current, which can be quantified using conventional voltammetry methods, allowing real-time monitoring of fluctuating concentrations of target analytes (11). Aptamer-based electrochemical detection has been utilized for the continuous monitoring of various drugs, including vancomycin and gentamicin, two essential antibiotics, in whole blood (12). Given the significant capabilities of aptamers, they are considered ideal candidates for biosensors designed to detect hVISA, as they can bind with high affinity and specificity. The benefits of employing aptamer-based biosensors for hVISA detection include their cost-efficiency, ease of modification, and ability to deliver quick results. Unlike conventional antibody-based techniques, aptamers can be synthesized with high purity, eliminating the need for extensive purification. In conclusion, aptamer-based biosensors offer a novel solution for the rapid detection of hVISA, fulfilling a vital need in managing infectious diseases. By leveraging the distinct properties of aptamers, these biosensors can enhance diagnostic precision and enable timely interventions for patients at risk of severe infections.

Conclusion

Aptamer-based biosensors hold considerable promise as rapid and adaptable tools for detecting hVISA. Their high specificity, potential for real-time monitoring, and ease of modification make them suitable for clinical applications where timely and accurate detection is critical. While further validation and integration into diagnostic workflows are needed, these biosensors could contribute meaningfully to early identification and improved infection control strategies against resistant *Staphylococcus aureus* strains.

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Ethics approval and consent to participate

This article does not contain any studies with animals performed by any of the authors.

Conflict of interest

The authors declare that they have no conflict of interest.

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