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A Rapid and Duplex MRSA Detection Method Using Molecular Beacons and SERS

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Abstract

Methicillin-resistant *S. aureus* poses a significant public health risk due to its resistance to multiple antibiotics. Accurate MRSA detection is paramount for effective treatment and containment of bacterial spread. A promising approach involves employing molecular biosensors based on Surface-Enhanced Raman Scattering (SERS). SERS is a robust analytical technique extensively applied in the detection of biological molecules.

Keywords: MRSA • Antibiotics • SERS

Introduction

In recent years, SERS-based biosensors have demonstrated significant promise in the realm of bacterial detection, including MRSA. This technique relies on the amplification of Raman scattering signals of analytes through plasmonic nanoparticles. Utilizing plasmonic nanoparticles as the SERS substrate not only enhances detection sensitivity but also enables the simultaneous detection of multiple targets [1].

One of the critical MRSA components ripe for detection is penicillin-binding protein (PBP). PBP is a bacterial protein pivotal in cell wall synthesis and serves as the target for various antibiotics, including beta-lactams. MRSA strains have evolved with altered PBPs, rendering them resistant to antibiotics and contributing to the emergence of MRSA strains. SERS-based biosensors designed for MRSA detection often incorporate molecular beacons as recognition elements. Molecular beacons are single-stranded oligonucleotides that adopt a stem-loop structure, labeled with Raman-active molecules. In the absence of the target, the molecular beacon maintains a closed conformation, extinguishing the Raman signal. When the target is present, the molecular beacon hybridizes with it, causing the stem-loop structure to open, releasing the Raman-active molecules, which are subsequently detectable through SERS [2].

Description

Plasmonic nanoparticles employed in SERS-based biosensors can undergo functionalization with specific antibodies or peptides that possess the ability to selectively bind to the target bacteria. This binding event between the bacteria and the functionalized nanoparticles amplifies the SERS signal, thereby facilitating the detection of bacteria even at low concentrations. The prospects of SERS-based molecular biosensors in the realm of MRSA detection are highly promising. Leveraging molecular beacons as the recognition element in conjunction with plasmonic nanoparticles as the SERS substrate enables the precise detection of MRSA strains. The incorporation of specialized antibodies or peptides further elevates the biosensors' sensitivity and selectivity. These biosensors hold significant potential for the development of portable point-of-care devices tailored for the swift detection of MRSA in clinical settings [3].

Methicillin-resistant S. aureus (MRSA) represents a formidable bacterial infection characterized by resistance to numerous antibiotics. MRSA infections can pose life-threatening consequences, underscoring the critical importance of early detection for effective treatment. Traditional MRSA detection methods are often time-consuming, necessitating bacterial culture and identification, which can lead to treatment delays and an increased risk of infection spread. In recent years, the advent of molecular beacon-based surface-enhanced Raman scattering (SERS) assays has ushered in a rapid and sensitive approach to MRSA detection. Molecular beacons, single-stranded oligonucleotides adopting a stem-loop structure and tagged with Raman-active molecules [4,5], play a pivotal role in this technique.

In the presence of the target, the molecular beacon hybridizes with it, causing the stem-loop structure to open and releasing the Raman-active molecules, detectable via SERS. This detection methodology offers exceptional sensitivity and specificity in MRSA detection due to the molecular recognition capabilities of the molecular beacon. SERS, a potent analytical technique widely employed for the detection of biological molecules, relies on enhancing Raman scattering signals of analytes through plasmonic nanoparticles. The utilization of plasmonic nanoparticles as the SERS substrate not only heightens detection sensitivity but also facilitates multiplexed detection.

A recent study presented a molecular beacon-based SERS assay tailored for the rapid and duplex detection of MRSA. This assay harnessed two distinct molecular beacons, each targeting a different MRSA gene-mecA and nuc. The procedure employed gold nanoparticles as the SERS substrate, complemented by a portable Raman spectrometer for detection. The study findings demonstrated the assay's capacity to detect MRSA at concentrations as low as 100 CFU/mL in clinical samples within a mere 30 minutes. Furthermore, the duplex assay exhibited exceptional specificity and sensitivity, enabling clear differentiation between MRSA-positive and MRSA-negative samples [6].

Conclusion

Employing a molecular beacons-based SERS assay for MRSA detection yields numerous advantages compared to traditional methods. This assay boasts rapidity, sensitivity, and specificity, facilitating the early identification of MRSA infections. Moreover, the duplex assay holds the promise of concurrently detecting multiple targets, enhancing its utility in clinical environments. The molecular beacons-based SERS assay presents an encouraging approach for swift and simultaneous MRSA detection. Its application has the potential to substantially enhance patient outcomes by enabling the timely identification of MRSA infections, thereby facilitating the prompt administration of appropriate treatment. Additionally, the creation of portable devices for MRSA detection

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using this assay may expand its utility in resource-constrained settings. Continued research and development efforts are imperative to fine-tune the assay for clinical deployment and assess its performance across larger patient populations.

Acknowledgement

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Conflict of Interest

None.

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