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Impedimetric Phage-Based Sensor for the Rapid Detection of Staphylococcus aureus from Nasal Swab

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Abstract : Pathogenic bacteria represent a threat to healthcare systems and the food industry because their rapid detection remains challenging. Electrochemical biosensors are gaining prominence as a novel technology for the detection of pathogens due to intrinsic features such as low cost, rapid response time, and portability, which make them a valuable alternative to traditional methodologies. These sensors use biorecognition elements that are crucial for the identification of specific bacteria. In this context, bacteriophages are promising tools for their inherent high selectivity towards bacterial hosts, which is of fundamental importance when detecting bacterial pathogens in complex biological samples. In this study, we present the development of a low-cost and portable sensor based on the Zeno phage for the rapid detection of Staphylococcus aureus. Screen-printed gold electrodes functionalized with the Zeno phage were used, and electrochemical impedance spectroscopy was applied to evaluate the change of the charge transfer resistance (Rct) as a result of the interaction with S. aureus MRSA ATCC 43300. The phage-based biosensor showed a linear range from 101 to 104 CFU/mL with a 20-minute response time and a limit of detection (LOD) of 1.2 CFU/mL under physiological conditions. The biosensor’s ability to recognize various strains of staphylococci was also successfully demonstrated in the presence of clinical isolates collected from different geographic areas. Assays using S. epidermidis were also carried out to verify the species-specificity of the phage sensor. We only observed a remarkable change of the Rct in the presence of the target S. aureus bacteria, while no substantial binding to S. epidermidis occurred. This confirmed that the Zeno phage sensor only targets S. aureus species within the genus Staphylococcus. In addition, the biosensor's specificity with respect to other bacterial species, including gram-positive bacteria like Enterococcus faecium and the gram-negative bacterium Pseudomonas aeruginosa, was evaluated, and a non-significant impedimetric signal was observed. Notably, the biosensor successfully identified S. aureus bacterial cells in a complex matrix such as a nasal swab, opening the possibility of its use in a real-case scenario. We diluted different concentrations of S. aureus from 108 to 100 CFU/mL with a ratio of 1:10 in the nasal swap matrices collected from healthy donors. Three different sensors were applied to measure various concentrations of bacteria. Our sensor indicated high selectivity to detect S. aureus in biological matrices compared to time-consuming traditional methods, such as enzyme-linked immunosorbent assay (ELISA), polymerase chain reaction (PCR), and radioimmunoassay (RIA), etc. With the aim to study the possibility to use this biosensor to address the challenge associated to pathogen detection, ongoing research is focused on the assessment of the biosensor’s analytical performances in different biological samples and the discovery of new phage bioreceptors.

Keywords : electrochemical impedance spectroscopy, bacteriophage, biosensor, Staphylococcus aureus
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