Biosensors Based Diagnostics Systems for Bacterial Pathogens

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Globally, infectious diseases are widespread. In order to start the proper antibiotic therapy and stop the infection from spreading, it is imperative to determine the microbiological origin of the infection. A fast and reasonably priced diagnostic test is required for delivery to community health care settings. The rise of multidrug resistance bacteria has been linked to empirical therapeutic techniques caused by the slow pace of clinical diagnosis. In comparison to traditional diagnostic assays, the introduction of nanoparticles promises to advance in-vitro diagnostics to a new level of performance. In order to increase detection sensitivity while shortening assay times, this work attempts to develop nanodiagnostics assays. In addition to aiming for speed and sensitivity, the tests were made to be reliable, cheap, and repeatable so that they could be used in poor countries' rural areas.

Keywords: Biomaterial, nanotechnology, pathogens, nano biosensors.

1. Introduction

Medical diagnosis greatly depends on the quick and accurate identification of harmful germs. The identification of pathogenic agents has predominantly depended on two methods: the microscopic observation of pathogens in clinical specimens or the cultivation of microorganisms in laboratory settings. These diagnostic methods are widely utilised in the developed world, but they are frequently ill-suited for use in developing countries, where access to clinical and laboratory facilities may be restricted and infectious diseases are a major cause of morbidity and mortality. Certain antibodies directed against a particular pathogen can be detected with a decent degree of sensitivity using immunoassays such fluor immunoassays and ELISA, whose findings can be obtained in a few hours. Furthermore, because molecular diagnostic tests (nucleic acid-based amplification tests) can provide test results from clinical, food, and environmental samples, they have a great deal of potential for usage in underdeveloped nations [1]. Amplification techniques such as PCR rely directly on the in-vitro increase of nucleic acid target rather than on the cultivation of more microorganisms [11]. Conventional diagnostic tests such as the ones listed above necessitate time-consuming sample preparation, large, cumbersome equipment, and delayed data readout [12]. To tackle the

increasing testing issues in developing nations, creative solutions for enhancing the performance of existing diagnostic assays must be developed. The identification of pathogenic pathogens has made extensive use of nanodiagnosis based on fluorescent, magnetic, and metallic nanoparticles. To fully optimise the use of these NPs in clinical diagnosis and to pave the way for in-vitro diagnosis in impoverished nations, more research has been conducted. [2].

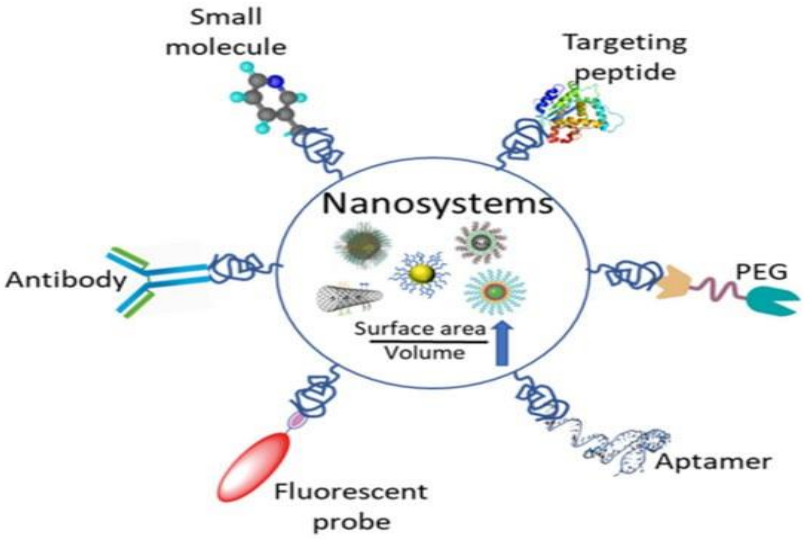

Figure 1: Nano diagnosis of Infectious Diseases

Scientific research on infectious diseases is actively focused on developing new diagnostic tests and refining those that already exist [13]. The World Health Organisation (WHO) has created a set of standards known as ASSURED that outline the best diagnostic procedure for underdeveloped nations.

In this instance, section 1 of the article examines the introduction, while section 2 examines the relevant literature. The purpose of the right to health is explained in Sections 3, and 4, the challenge of the proposed work is discussed in Section 5, and the project is concluded in Section 6.

2. Literature Review

In order to increase the sensitivity detection of infectious pathogens for the poor world, researchers have taken advantage of the special features of nanomaterials. Working at the atomic, molecular, and supramolecular scales in the range of 1–100 nm is a component of nanotechnologies. Nanodiagnostics is the use of nanoparticles (NPs) as signalling probes to diagnose infectious diseases [6]. Since nanoparticles have a huge surface area, many target-specific proteins of interest can be attached for extremely sensitive detection. Additionally, NPs have a strong structural foundation and may be tailored to have certain physical, optical, and magnetic properties by varying their size, shape, and composition [9]. These qualities may find use in biological and environmental studies [11]. The application of nanotechnology for infectious pathogen identification would benefit from all these alluring properties, particularly

in environments with limited resources. Therefore, it is believed that nanodiagnostics can provide clinical diagnoses at a low cost, particularly in underdeveloped nations [4].

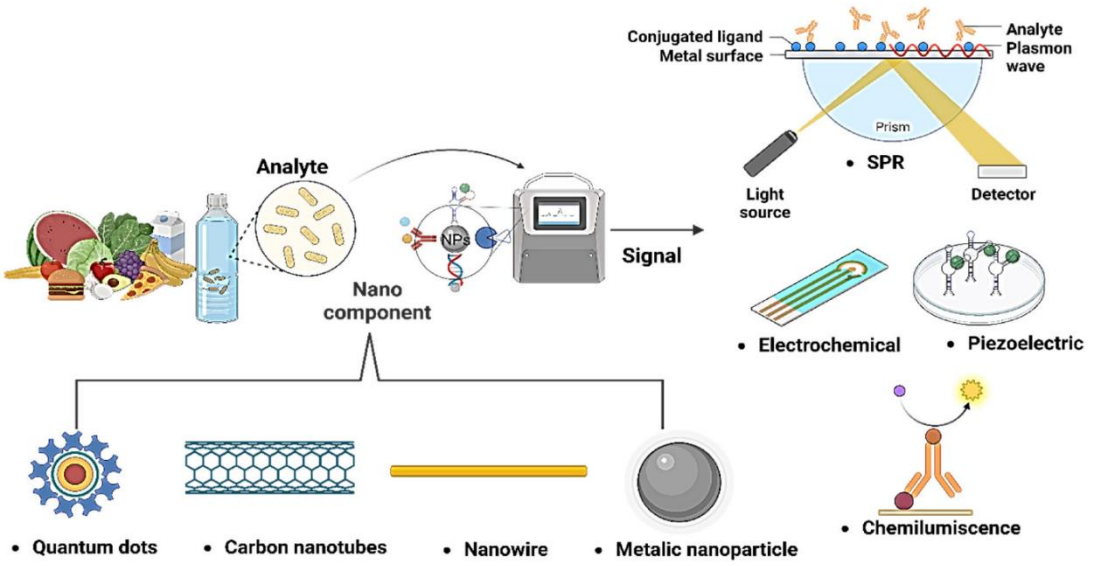

Figure 2: Nano biosensors for diagnostics of bacterial pathogens

3. Nanodiagnosis Of Infectious Diseases

The identification of pathogenic pathogens has made extensive use of nanodiagnosis based on fluorescent, magnetic, and metallic nanoparticles. To fully optimise the use of these NPs in clinical diagnosis and to pave the way for in-vitro diagnosis in impoverished nations, more research has been conducted.

- Gold nanoparticles-based diagnosis.

The first uses of NPs in point-of-care (POC) disease detection is the use of AuNPs in immunochromatographic tests (ICTs) [7].

ICT depends on liquid migrating across the nitrocellulose membrane's surface, as seen in Figure 3. The test sample's bacteria react with the sample pad's AuNPs conjugate, trapping the immune complex and immobilising it with a capture antibody to provide the red colour signal. The free AuNPs conjugated with the antibody travel further and become stuck in the control line. To confirm that the compound antibody was active and had moved across the membrane, a control line containing anti-goat or anti-mouse IgG specific to the conjugate antibody was employed. The target analyte was detected because the red colour produced by the AuNP buildup in the test line and control line could be seen with the naked eye.

- Magnetic nanoparticles based diagnosis

It has been shown that magnetic nanoparticles (MNPs) have interesting and potential applications in immunoassay-based and medical diagnostics. Lower sample preparation is required since the MNPs coupled to the target-specific antibody have a better capture

efficiency. Without surface plating enrichment, the streptavidin-coated MNPs were utilised to specifically capture Escherichia coli O157 from a ground beef sample, with a detection limit of 1.6 x 101 to 7.2 x 107 cfu/ml in 15 minutes. Aside from antibodies, affinity probes such as tiny compounds like vancomycin—which binds to D-Ala-D-Ala moieties on bacterial cell walls—were employed. It has been observed that vancomycin-modified MNPs can selectively capture both gram-positive and gram-negative bacteria from sample solutions [8]. Staphylococcus aurues and saprophylococcus saprophyticus were isolated from a urine sample using vancomycin-coated MNPs. To detect species level information, the separated cells were subjected to MALDI-TOP analysis. Using MALDI-TOP, this technique could distinguish Staphylococcus from a sample containing 7 x 104 cfu/ml. Moreover, the carbohydrates can be utilised to create magnetic glyconanoparticles by combining them with MNPs.

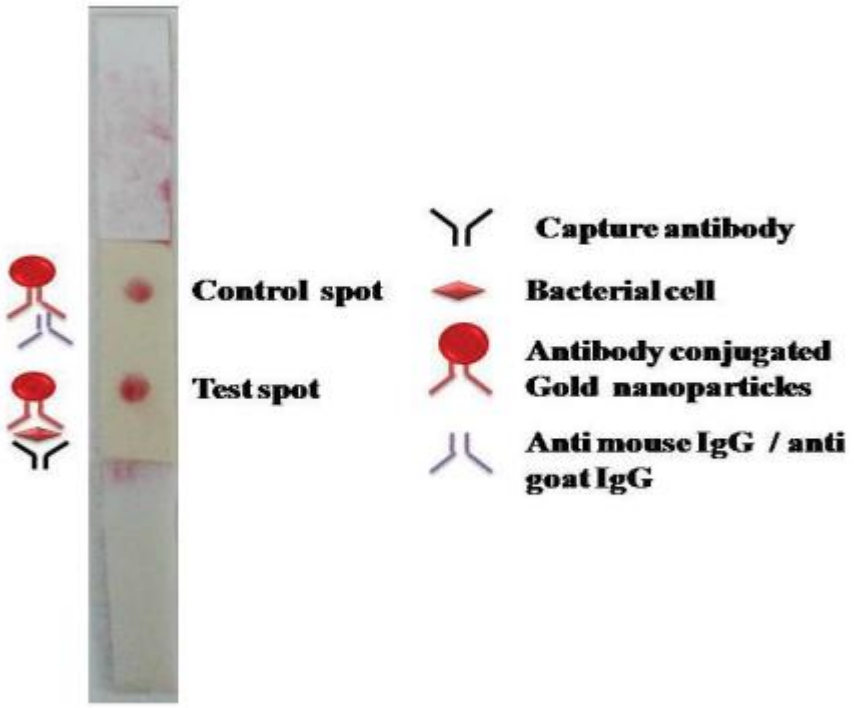

Figure 3 Schematic of ICT assay using AuNPs probes

- Fluorescence nanoparticles based diagnosis

Assays based on QD and dye-doped silica nanoparticles have attracted a lot of interest for the biosensing and bioimaging of pathogenic diseases. For highly sensitive bacterial counting in the range of 3 x 102 cfu/ml, the CdSe/ZnS/SiO2 nanocomposite was covalently linked directly with bacteria using glutaraldehyde crosslinker [14]. In one investigation, multicolor FRET was utilised to multiplex bacterial detection using SiNPs doped with three different dyes. This was accomplished by altering the proportion of the three dyes contained within the SiNPs, producing NPs with a single wavelength of excitation and distinct colour emission.

4. Recent Trends In Point – Of – Care Diagnostics

Self-standing analytical equipment that are portable and simple to operate are essential for point-of-care (POC) diagnosis. The assay system should enable integration of straightforward analytical techniques and detection in the compact device in order to satisfy POC diagnostic needs. When using the fluorescence immunoassay in the field, portable instruments are always required for sample readout. A portable laptop-controlled system with a CCD spectrophotometer and an LED light source for illumination was described as a means of measuring fluorescence. Escherichia coli O157 was demonstrated to be detectable by this portable device using an IMS-QD based immunoassay [10]. These days, it has been demonstrated that microfluidic systems offer a complete solution for biological and chemical analysis, from the application of the sample to the display of the analysis results. A low-cost optical microfluidic biochip was created by combining silica-on-silicon photonic waveguides with optical components with microfluidic architecture. This hybrid biochip was shown to detect fluorescence in QDs using a laser-induced fluorescence in a low-cost, portable lab on chip platform.

Recently, a fully integrated, low-cost sample-to-answer qPCR system has been designed and evaluated for the point-of-care detection of HIV-1 proviral DNA in babies in resource-constrained situations. This system is built on a new technique for extracting DNA that makes use of a glass fibre membrane, a disposable assay card with built-in reagent storage, features for temperature cycling, and a portable, battery-operated analyzer. The device can perform qPCR and automated PCR mix assembly with a new reagent delivery mechanism. Such a POC HIV-1 qPCR test would significantly accelerate the speed of detection in areas with limited resources. High-quality and reasonably priced channel sealing was used to package a different photonic microfluidic integrated device that was created in a monolithic planar manner employing a system of micro lenses and waveguides coupled with microfluidic channels on chip. Photonic components placed into the chip for usage in scatter and fluorescence detection and counting applications are demonstrated for this optofluidic system. According to Watts et al. (2012), this device's performance can complement traditional flow cytometry-based detection. Apps for remote detection and POC are made possible by such device designs.

5. Conclusion

In conclusion, novel sensitive nanodiagnostics are already being developed, and it is feasible that they will be integrated into lab-on-a-chip technologies using portable and miniaturised optical detecting techniques. Before nanodiagnosis is genuinely prepared for usage in developing nations, a few issues must be resolved. Appropriate selection of antibodies and nucleotide targets is essential for increasing the specificity of diagnostics based on nanotechnology and enabling multiplex species level detection. However, the WHO's list of obstacles to the provision of quick and affordable POC testing can be addressed by nanotechnology. This thesis examines several NP surface changes, the bioconjugation of NPs with DNA and antibodies, techniques for the quick identification of bacterial pathogens from clinical and food samples, and the development of related prototype devices.

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