Nanotechnology Based on Treatment of Cancer and Covid-19

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ABSTRACT

The 1980s marked the beginning of nanotechnology, which involves the synthesis, manipulation, and visualization of materials at the nanometre scale. Although much of this work remains in research laboratories, the first nanotechnology-based medicines, vaccines, tablets, and diagnostic devices are increasingly gaining scientific and commercial importance. This review discusses recent advances in nanomedicine for combating antibiotic resistance, treating and detecting cancer, and managing neurodegenerative diseases. Nanotechnology is also expected to bring significant changes to immunotherapy through the development of vaccine implants that continuously regulate and enhance immune responses over time. Nanomedicine has played an important role in the development of COVID-19 vaccines, particularly mRNA vaccines formulated using lipid nanoparticles, such as those developed by Pfizer-BioNTech and Moderna. Nanotechnology also offers promising approaches for the early diagnosis and timely treatment of cancer. DNA nanotechnology has emerged as a useful technique for fabricating nanoscale structures and devices. In recent years, nanotechnology has been increasingly applied to human healthcare, particularly in cancer diagnosis and treatment. Furthermore, nanotechnology and nanomedicine have the potential to improve existing approaches and develop new strategies for combating COVID-19. Nanomaterials may also be used to develop efficient and reusable personal protective equipment and antiviral coatings for public environments, potentially helping to reduce the spread of SARS-CoV-2.

Keywords: Nanotechnology, cancer, COVID-19, nanomedicine, neurodegenerative diseases, nanomaterials

INTRODUCTION

Nanotechnology involves the manipulation of matter at the atomic, molecular, and supramolecular levels. It includes the design, production, characterization, and application of nanoscale materials for various purposes, particularly in medicine. Nanotechnology has considerable potential in several medical fields, including immunology, cardiology, endocrinology, ophthalmology, oncology, and pulmonology. It is also used in specialized applications such as brain targeting, tumour targeting, and gene delivery. Furthermore, nanotechnology provides advanced structures, devices, and materials for pharmaceutical applications [1].

The prefix nano originates from the Greek word meaning “dwarf” or something very small. One nanometre is equal to one-billionth of a metre (m). Nanoscience refers to the study of structures and molecules at the nanoscale, generally ranging from 1 to 100 nm, whereas nanotechnology involves the practical application of this knowledge to develop useful materials, devices, and systems [2].

Nanotechnology is considered one of the promising technologies of the twenty-first century. It involves transforming scientific knowledge at the nanoscale into practical applications through the observation, measurement, manipulation, assembly, control, and manufacture of matter. The National Nanotechnology Initiative (NNI) in the United States defines nanotechnology as science, engineering, and technology conducted at the nanoscale, where unique phenomena enable novel applications across chemistry, physics, biology, medicine, engineering, and electronics [3].

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The synthesis of engineered materials, particularly nanomaterials, has increased rapidly over the past three to four decades. These materials have a wide range of applications in engineering, waste management, sports equipment, electronics, optics, apparel, food, cosmetics, and other areas of daily life [4,5].

Nanomedicine can help overcome challenges associated with the site-specific delivery of antiviral drugs. In the case of COVID-19, optimized nanomedicine-based drug delivery systems may improve the delivery of antiviral agents to targeted sites. Nanomedicine can also provide controlled drug release and protect antiviral drugs from degradation, thereby contributing to the management of viral infections. High doses of antiviral drugs distributed to non-target tissues may cause adverse effects, which can sometimes be more harmful than the infection itself [6].

Although the lungs are the primary target of SARS-CoV-2 infection, other systems, including the cardiovascular system, kidneys, liver, central nervous system, and immune system, may also be affected by COVID-19 [7]. The major symptoms of COVID-19 include fever, myalgia, and fatigue, while some patients may experience headache, haemoptysis, and sputum production [8].

NANOTECHNOLOGY IN CANCER TREATMENT

Cancer metastasis is a major cause of treatment failure and cancer-related deaths. Many patients already have detectable metastases or undetectable micrometastases when cancer is diagnosed, making surgical removal alone an unsuitable treatment option in some cases [9].

Nanotechnology has considerable potential to address the limitations associated with biological drugs, including monoclonal antibodies (mAbs) used in cancer immunotherapy. The administration of biological drugs may lead to the formation of anti-drug antibodies (ADAs), which can adversely affect their safety and therapeutic efficacy [10].

Nanotechnology is increasingly recognized as a promising approach for improving the delivery, efficacy, and safety of cancer therapeutics, including therapeutic proteins and immunotherapeutic agents [11]. Immunotherapy aims to use the patient's immune system to fight cancer by activating immune cells to recognize and eliminate cancer cells [12].

The diagnosis of cancer generally requires confirmation through biopsy and histopathological examination before treatment is initiated [13]. In this context, nanotechnology has emerged as a promising approach for cancer detection and treatment. It involves engineering and manipulating materials at the nanoscale, generally within the range of 1–100 nm. The unique physicochemical properties of these materials influence their interactions with cells and tissues, providing opportunities for developing nanoscale targeting strategies that may improve cancer diagnosis and treatment [14].

NANOTECHNOLOGY IN COVID-19

In 2020, the world experienced a major public health crisis caused by SARS-CoV-2, the virus responsible for COVID-19 [15]. The virus was first identified in Wuhan, China, and subsequently spread worldwide [16].

The progression of the COVID-19 outbreak has been described in different stages. The first stage involves the importation of infected cases into a country from another affected region. The second stage involves local transmission from infected individuals. The third stage is community transmission, in which the source of infection may become difficult to identify. The fourth stage represents widespread transmission within a population, potentially continuing without a clearly defined endpoint [17].

To improve immunization effectiveness and provide alternatives to conventional vaccine technologies, several nanotechnology-based vaccines have been developed and investigated against SARS-CoV-2 [18].

Nanotechnology is closely related to biomimetic technology because viruses themselves are nanoscale biological structures. Understanding their structure and behaviour is therefore relevant to the development of

nanomedicine. Nanomedicine integrates knowledge from bioengineering, pharmacology, biology, physics, materials science, photonics, and computational science [19].

Two major strategies for developing antiviral drugs are drug repurposing and the discovery of new drugs. Drug repurposing involves investigating existing medicines for new therapeutic uses and may reduce the time required for drug development. During the COVID-19 pandemic, several medicines, including chloroquine, hydroxychloroquine, remdesivir, tocilizumab, lopinavir/ritonavir, ivermectin, and azithromycin, were investigated for potential therapeutic effects against COVID-19. Their clinical effectiveness varied, and investigational use should not be interpreted as evidence of established efficacy [20].

Researchers in nanomedicine have also investigated the relationship between gene-delivery systems, nanoscale materials, and viral vectors to improve the delivery of genetic material into cells [21,22]. Nanoparticles can be designed to reproduce certain structural and functional properties of viruses, making them useful platforms for developing innovative vaccine and drug delivery technologies [23–25].

CONCLUSION

Nanotechnology involves the manipulation of matter at the atomic, molecular, and supramolecular levels. Recent advances in nanotechnology have contributed to the development of new approaches for cancer diagnosis and treatment. These technologies may also help monitor cancer progression and treatment responses, potentially supporting the development of improved therapeutic strategies.

Significant progress has been made in nanotechnology-based cancer diagnosis and treatment over the past decade. Nanomedicine has also contributed to the development of vaccines and other biomedical technologies for combating SARS-CoV-2. Earlier outbreaks of SARS and MERS did not receive the same level of sustained vaccine development as COVID-19, partly because of differences in outbreak duration, transmission, and funding priorities.

The COVID-19 pandemic demonstrated the potential of nanomedicine in vaccine development and other biomedical applications. Lipid nanoparticle-based mRNA vaccines represent an important advancement in this field. Overall, nanotechnology offers promising approaches for addressing challenges in cancer diagnosis and treatment, vaccine development, and the management of infectious diseases. Continued research is necessary to improve the safety, efficacy, and clinical applicability of nanotechnology-based medical products.

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