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Applications of Nanotechnology in Medicinal Chemistry Impact

Dr. M. SARASIJA [1*]

[1]*Assistant professor, University college of science Satavahana University, Karimnagar.*

Abstract

Nanomedicine is a broad use of nanotechnology in the medical domain. Particular nanoparticles may be used in imaging and methods, biomedical implants, targeted pharmaceutical products, tissue engineering, and novel diagnostic tools. An overview of the many studies on the use of nanotechnology in medicinal chemistry may be found in this article. According to the review, nanotechnology helps to maximise therapeutic efficacy, minimise the risk of adverse effects, and address the issue of focussed therapy delivery. This method is appropriate for cancer detection, treatment, and gene therapy. The realm of nanomedicine is where nanorobotics has the most potential for application. It is used in a wide range of sectors, including the creation of vaccines, medicine delivery, wearable technologies, diagnostic and imaging equipment, and antimicrobial products. Early illness detection, more powerful drugs, and improved equipment are expected to lead to nanomedicine. Combining conventional anti-cancer medications with nanoscale technology allows them to pass through intact and circulate throughout the brain. This technique provides whole classes of existing medications, as well as vast new markets and advantages.

Keywords: Nanotechnology, Nanoparticles, Medicinal and pharmaceutical products, Medicinal chemistry, Nanomedicine, etc.

1 Introduction

Materials, devices, systems, and structures that are planned, described, produced, and used in ways that exploit nanoscale phenomena are referred to as "nanotechnology" in science and engineering. As a new

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approach to medical research, nanotechnology is now regarded as the most potential technology of the 21st century [1]. Over the last ten years, public investment for nanotechnology development and research has grown, indicating that nanotechnology will bring in a new age of productivity and wealth. Economic development may be stimulated by nanotechnology, which can also improve industrial sectors' capacity and quality. It has greatly influenced the wellbeing of society and shaped contemporary existence. It might fundamentally change human existence, economic circumstances, and cultural dynamics [2], [3].

A. Need for nanotechnology in the medical field

The field of nanotechnology and nanomedicines is so broad and diverse. Significant advancements in nanomedicine have elevated the medication to a new degree with noteworthy medical consequences. Studying nanotechnology's important potential in healthcare is necessary. Nephrology and cardiovascular disease In addition to cancer treatment and therapeutic genes, numerous medical specialities are currently conducting extensive research on the most effective methodologies and best practices [4]. The conventional therapy has made substantial progress, and the purity of nanoparticles and nanotechnology has both improved, resulting in positive outcomes. In gene therapy, nanomedicines have also been used. Many investigations on viral vectors as possible drug delivery vehicles were undertaken. Information from smart tablets and nanobots aimed at specific cancer cells are gathered by researchers to ensure that patients get the appropriate treatment [5]. By replacing current methods with more affordable and user-friendly alternatives, nanotechnology presents the possibility of in-vitro diagnostics. Nanoparticles may function as molecular imaging agents in these technologies, impacting the functional features of tumour cells and genetic alterations associated with cancer [6]. Additionally, the following nanomaterials are typically included in functional nanotechnology-based coatings, depending on their intended application: zinc oxide, iron oxide, silicon dioxide, carbon black, and silver. Tools and procedures are utilised in the field of medical device engineering to improve the safety, efficacy, and physiochemical characterisation of "nanomaterials and nanosurfaces". When developing products using new materials, sensors, and energy storage devices, scientists are essential [2].

B. Nanotechnology and cancer treatment

As the number of cancer patients worldwide rises, there is an urgent need for an inventive pharmaceutical delivery system that is more targeted, efficient, and has fewer side effects, as well as an accurate detection approach. If the therapeutic drug can reach the targeted location without causing any unfavourable side effects, anticancer therapies are often thought to be more successful [7]. To enhance this necessary targeted delivery, nanoparticle carriers' surfaces may be chemically modified. Polyethylene oxide, or PEG, is one of the best methods for altering the surface of nanoparticles. These changes improve the cancer targeting capability in addition to the medication uptake's specificity. The nanoparticles may pass through the blood until they hit the tumour because PEG stops the immune system in the body from recognising them as foreign substances [2]. Hydrogel's application in the treatment of breast cancer is a great example of this innovative technology. One kind of monoclonal antibody called Herceptin targets the human epidermal growth factor receptor 2 (HER2) on cancer cells to treat breast cancer. This has led to the development of a vitamin E-based hydrogel that can transport

Herceptin to the target spot for a few weeks with a single dosage [8]. It is a better anti-tumor agent because Herceptin is better maintained within the tumour when administered via hydrogel, which is more effective than "conventional subcutaneous and intravenous delivery techniques". Nanotechnologies may be used to modify nanoparticles in a variety of ways to improve drug localisation, boost medication effectiveness, extend circulation, and perhaps slow the development of multidrug resistance [9].

C. Nanoparticles in MRI

Cancer tumour MRI imaging is enhanced by iron oxide nanoparticles. Iron oxide nanoparticles are functionalised using aptamers, antibodies to the epthelial growth factor receptor, or short peptides such as "arginyl glycyl aspartic acid (RGD)". The “kidney, stomach, liver, breast, colon, and brain cancers” are among the cancers for which they have been suggested. Additionally, synthesised iron oxide nanoparticles may be used in research on brain inflammation and early thrombosis detection. Additionally, iron, manganese, and gadolinium nanoparticles may be used for MRI imaging. MRI research often uses these nano-objects for biological applications due to their electrical and structural band gap positions [10].

D. Nanotechnology in Diagnostic imaging.

"Computed tomography, magnetic resonance imaging, nuclear medicine, X-rays, and ultrasound" are popular imaging techniques that are often used in biochemical and medical research [11]. But only at a somewhat late stage of the disease can these methods look at changes on the surface of the tissue. They might be enhanced by using contrast and nanotechnology-based targeting agents to identify the sick region at the tissue level, improving resolution and specificity [12]. Nowadays, the majority of contrast agents used in medical imaging are small molecules with the potential for unfavourable side effects because of their rapid metabolism and non-specific distribution [13]. More stronger contrast agents for almost all imaging modalities might be made using nanoparticles as they are less harmful and have superior permeability and retention effects in tissues. This is the area in which nanotechnologies have the greatest impact on medicine. The size of the nanoparticles has a significant impact on their "biodistribution, blood circulation half-life, cellular absorption, tissue penetration, and targeting" [9], [14].

2 Literature Review

(Karahmet Sher et al., 2024) [7] investigations into nanoparticles and nano-delivery systems, focussing on their uses in virology and cancer, including both in vitro testing conducted on cell cultures and in vivo evaluations conducted on suitable animal models. This offers a fresh viewpoint by combining many elements, such as structure and formation, as well as their relationship to distinctive behaviours in organisms. Additionally, the usefulness of these systems in pharmacy and medicine was investigated, with an emphasis on cancer and viral infections. The findings suggest that the use of nanotechnological solutions to deliver medications and enhance therapeutic effects will only grow.

(Haleem et al., 2023) [2] explores the many kinds of nanoparticles that are used in medicine. explains the use of nanotechnology in the medical sector as well. The class, attributes, and features of medical nanotechnology are also provided. Collaboration across sectors will be necessary for scientists, governments, community organisations, and the general public to assess the significance of nanotechnology and guide its growth in several fields. Several potential applications of nanotechnology in the medical area are being investigated at this time. "Scientists, engineers, and researchers" will discover the study's succinct and organised summary on nanotechnology helpful for their future research.

(Sim & Wong, 2021) [9] Nanotechnology is the process of taking use of a material's unique properties at the nanoscale. In several industries, nanotechnology has gained popularity due to its ability to create smarter and better-built products. Cancer and heart disease are among the most prevalent illnesses that have been treated by nanomedicine, an application of nanotechnology in medicine. The author gives a summary of the most current developments in nanotechnology as they relate to medication delivery and imaging.

(Altammar, 2023) [5] Because of their adaptability and superior performance over their parent material, nanoparticles (NPs) are crucial for technological advancements. Hazardous reducing agents are often used to convert metal ions into uncharged nanoparticles for their manufacturing. However, a lot of efforts have been made recently to develop green technology that produces nanoparticles using natural resources rather than hazardous chemicals. Environmentally friendly, clean, safe, economical, simple, and very productive, biological approaches are used in green synthesis to synthesise nanoparticles. The green synthesis of NPs uses a wide variety of biological organisms, including plants, bacteria, actinomycetes, fungi, algae, and yeast. This study will also cover nanoparticles, including their kinds, characteristics, production techniques, uses, and future possibilities.

(Malik et al., 2023a) [15] being out in order to integrate the most recent information on pharmacological and medical applications of nanotechnology from recognised scientific sources. Nanotechnology is being effectively used in the fields of "diagnostics, diseases, regenerative medicine, gene therapy, dentistry, cancer, cosmetics, drug delivery, and therapeutics". Future developments in the area of nanomedicine will be more planned, structured, and technically programmed if doctors, clinicians, researchers, and technology work together and are thoroughly associated. Due to the pathophysiological basis of diseases, advancements are being made in overcoming barriers associated with the application of nanotechnology in the medical field. The many facets of nanomedicine are highlighted in this article, along with the ways that nanotechnology is helping the medical field. Minimising the detrimental impacts of nanotechnology on ethics, the environment, and human health is imperative.

(Abaszadeh et al., 2023) [16] Examine the applications of nanotechnology in minimally invasive "surgery, cardiac surgery, vascular surgery, ophthalmic surgery, neurosurgery, plastic surgery, orthopaedic surgery, surgical oncology, and thoracic surgery". Among other topics, it talks about the use of nanomaterials in breast implants, bone grafting, and implant surfaces. The article also discusses the many applications of nanotechnology, such as haemostasis, nerve repair, nanorobots, stem cell-incorporated nanoscaffolds, nano-surgery, and diagnostic applications. Additionally discussed are the safety and ethical ramifications of using nanotechnology in surgery. Nanotechnology's potential is explored, suggesting a path towards better patient outcomes. The last section of the article discusses the revolutionary impact of nanotechnology in surgical applications and its potential for further advancements.

(Anjum et al., 2021) [17] Nanomedicine, the use of nanotechnology and related nanocarriers and nanosystems in medicine, has improved disease prevention, diagnosis, and treatment in a number of ways. It has been discovered that some nanosystems are better suitable for theranostic applications than traditional techniques. The usage and limitations of medically relevant nanosystems in areas including gene therapy, targeted drug delivery, and treatment of cancer and other genetic diseases will be discussed in this review paper. Although nanotechnology has a lot of potential, it has not yet been fully utilised, and more work must be done to overcome these restrictions and utilise it to its fullest potential in order to transform the healthcare industry in the near future.

3 Conclusion

Innovative technology has often been developed with healthcare as its primary emphasis since it is a fundamental human right. The delivery of timely, acceptable, high-quality, and reasonably priced healthcare has been greatly aided by technological advancements. The development of nanoscience has led to the emergence of new types of nanostructures. The advent of nanotechnology has been a game-changer in medicinal chemistry, opening the door to focused treatment with fewer systemic adverse effects and better drug transport, solubility, and bioavailability. The use of nanoparticles in drug and gene delivery has led to significant advancements in treating cancer, rare diseases, and infections while minimizing damage to healthy tissues. Nanotechnology-based sensors and real-time monitoring devices facilitate early disease detection and personalized treatment plans. In surgical applications, nanomaterials enhance imaging, wound healing, and targeted medication delivery, reducing complications and improving precision. Nano-dentistry is emerging as a promising field, utilizing dendrimers for gene and drug delivery. Various nanomaterials, including metallic nanoparticles, quantum dots, and CNTs, have shown potential in diagnostics, particularly in cancer imaging through MRI contrast agents like iron oxide nanoparticles. Additionally, nanotechnology has improved orthopedic implants, spinal fusion efficiency, and vaccine formulations by enhancing antigen solubility and controlled release. With applications spanning drug development, diagnostics, surgery, and personalized medicine, nanotechnology continues to advance healthcare by improving treatment efficacy, reducing adverse effects, and enhancing patient outcomes.

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