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Nanotechnology in Drug Delivery

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ABSTRACT

Nanotechnology plays a crucial role in modern drug delivery, offering innovative solutions for targeted and efficient drug delivery. By using nanoscale materials like nanoparticles, nanotubes, and dendrimers, nanotechnology allows for improved drug absorption, extended circulation times, and reduced side effects. These nanoscale carriers can encapsulate drugs, protect them from degradation, and deliver them to specific target sites in the body, like cancer cells or brain tissues, according to a study by the National Institutes of Health (NIH)

KEY WORDS: Nanotechnology,Novel drug delivery system,Nanoparticles,Nanotyubes,Improved absorption,Reduced side effects.

Introduction

Drug delivery systems (DDSs) have been used in past eras to treat numerous ailments. All medicines rely on pharmacologic active metabolites (drugs) to treat diseases [1]. Some of the drugs are designed as the inactive precursor, but they become active when transformed in the body [2]. Their effectiveness depends on the route of administration. In conventional drug delivery systems (CDDSs), drugs were delivered usually via oral, nasal, inhaled, mucosal, and shot methods [3]. The conventionally delivered drugs were absorbed less, distributed randomly, damaged unaffected areas, were excreted early, and took a prolonged time to cure the disease [4]. They were less effective due to many hurdles like their enzymatic degradation or disparity in pH, many mucosal barriers, and off-the-mark effects, and their immediate release enhanced toxicity in blood [5].Due to all such reasons, the Novel drug delivery system was developed.

Nanotechnology is the study of extremely tiny things and is basically the hub of all science disciplines including physics, chemistry, biology, engineering, information technology, electronics, and material science [6]. The structures measured with nanotechnology range from 1–100 nm at the nanoscale level [7]. Nanoparticles have different material characteristics because of submicroscopic size and also provide practical implementations in a wide range of fields including engineering, drug delivery, nanomedicine, environmental indemnification, and catalysis, as well as target diseases such as melanoma and cardiovascular diseases (CVD), skin diseases, liver diseases, and many others [8].Therefore, medicines linked with nanotechnology can enhance efficiency of medicines and their bioavailability and enhance their ability to penetrate biological barriers. This approach allows for controlled drug release, reduces side effects, and can bypass the first-pass metabolism, leading to better drug efficacy [9].

Nanotechnology uses nanoparticles (typically less than 100 nm) made from various materials (metals, lipids, polymers, biological materials) to encapsulate drugs. These nanoparticles can protect drugs from degradation in the body, especially in the digestive tract, allowing them to reach the bloodstream and target tissues more effectively. The nanoparticle structure can be designed for controlled release of the encapsulated drug, leading to sustained therapeutic effects and minimizing fluctuations in drug concentration in the blood[10].

Nanotechnology can address challenges associated with drugs that are poorly soluble in water or have low oral bioavailability. It can bypass the liver, preventing the degradation of drugs during the first pass through the liver and can overcome drug resistance mechanisms in cancer cells by enhancing drug delivery and minimizing the impact of drug efflux pumps.Nanotechnology has revolutionized the field of pharmacy by providing innovative solutions for drug delivery, diagnostics, and therapeutics.

Here are some key applications:

- Targeted Drug Delivery: Nanoparticles can be engineered to deliver drugs directly to specific cells or tissues, reducing side effects and improving therapeutic efficacy. For instance, liposomal formulations are used in cancer treatment to target cancer cells while minimizing harm to healthy cells [11].
- Controlled Release Systems: Nanoparticles can be designed to release drugs in response to specific stimuli, such as pH or temperature changes, allowing for controlled drug release. This can improve drug stability, bioavailability, and patient outcomes [12].
- Improved Bioavailability: Nanoparticles can enhance drug solubility and bioavailability, making them more effective. Nanosuspensions, for example, are used to improve the solubility of poorly soluble drugs [13].
- Cancer Treatment: Nanotechnology-based drug delivery systems, such as liposomes and polymeric nanoparticles, are being explored for cancer treatment. These systems can target cancer cells, reduce side effects, and improve treatment outcomes [14].

- Vaccine Delivery: Polymeric nanoparticles are being used in vaccine delivery to improve the efficacy and safety of vaccines.
- Dermatological Applications: Nanotechnology is being used to develop topical formulations for skin conditions, such as resveratrol-loaded nanoparticles for skin care .
- Ocular Drug Delivery: Nanotechnology-based ocular drug delivery systems are being developed to improve the treatment of eye diseases.
- Imaging and Diagnostics: Nanoparticles can be used as contrast agents for imaging and diagnostics, allowing for earlier disease detection and treatment. Some of the key benefits of nanotechnology in pharmacy include.
- Precision Medicine: Nanotechnology enables targeted drug delivery, reducing side effects and improving treatment outcomes.
-Improved Drug Solubility: Nanoparticles can enhance drug solubility, making them more effective.
- Enhanced Bioavailability: Nanoparticles can improve drug bioavailability, reducing the required dosage and minimizing side effects.[15]

DISCUSSION

Nanotechnology can enable personalized medicine by tailoring drug delivery to individual needs. This can be used to deliver combination therapies, enhancing treatment outcome and can be used as contrast agents for imaging and diagnostics, enabling earlier disease detection. Along with its benefits we can see various challenges like Ensuring the safety and toxicity of nanoparticles is crucial, Scaling up nanoparticle production while maintaining reproducibility is a challenge and establishing regulatory frameworks for nanotechnology in pharmacy is essential.

CONCLUSION

Nanotechnology has revolutionized the field of pharmacy by enabling the development of more effective, targeted, and personalized drug delivery systems. Through the use of nanoparticles, liposomes, dendrimers, and other nanocarriers, medications can now be delivered with greater precision, reducing side effects and improving therapeutic outcomes. Nanotechnology also enhances drug solubility, stability, and bioavailability, making treatments more efficient and patient-friendly.

Moreover, it offers promising advances in diagnostics, imaging, and regenerative medicine, paving the way for early disease detection and innovative therapies. While challenges such as regulatory approval, long-term safety, and manufacturing scalability remain, the integration of nanotechnology into pharmacy continues to grow and holds immense potential to transform healthcare in the years to come.

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