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Nanotechnology enables HIV/AIDS treatment and prevention.

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ABSTRACT

The HIV/AIDS pandemic is becoming more prevalent across the globe, with devastating health-related and socioeconomic effects. Antiretroviral therapy has had a significant impact on the life quality and expectancy of infected individuals, but the limitations of the currently available drug regimens and dosage forms, and the virus's exceptional adapting capacity, have hindered further success. Effective and practical preventative strategies are key to preventing the increasing number of new infections. Engineered nanosystems can significantly enhance current antiretroviral therapy, as evidenced by recent advancements in drug delivery. Furthermore, the HIV/AIDS epidemic persists because there is no cure or vaccine available. While combination antiretroviral treatment has greatly improved patient outcomes, it still requires continuous treatment, has serious side effects, and is not effective for those with resistance to viruses. Nanomedicine is a modern illustration of how nanotechnology, a science that spans multiple disciplines, is influencing healthcare in the 21st century. Over time, it could have a significant impact on HIV/AIDS treatment and prevention. This paper examines the obstacles of current HIV/AIDS treatment, followed by a discussion of how nanotechnology can boost the efficacy of antiretroviral therapy and gene therapy.

Introduction

Nanotechnology involves constructing and manipulating systems and materials that possess at least one feature that can be measured in nanometers or billionths of a meter. Physicochemically speaking, particles in this size range are different from bulk materials (macroscopic or microscopic scale) or individual atoms or molecules (atomic scale). Nano particulate interaction with biological systems is greatly influenced by their physicochemical properties. Other biological processes, such as detecting immunologically and crossing biological barriers, are also influenced by size concerns. When medicines are developed at the appropriate nanoscale dimensions, they may possess distinct physicochemical and biological characteristics that have therapeutic advantages over traditional treatments. Nanotechnology research has the potential to benefit those who have HIV once the issues with HIV and its treatment are resolved. The development of a treatment for AIDS/HIV has been pursued by scientists for more than 30 years. The initial focus of therapy was on antiretroviral medications, despite their inconsistent effectiveness. The FDA has given approval to 25 drugs beginning with Zidovudine in 1987. Many of these drugs are available in fixed-dose combinations and 8 formulations that are appropriate for use in low-resource areas. However, only Zidovudine and Didanosine are currently available in the USA as genuine generics. In the middle of the 1990s, HIV/AIDS treatment underwent a complete transformation with the arrival of protease inhibitors and triple-drug therapy. This marked the beginning of the era of highly active antiretroviral treatment (HAART), where HIV patients are treated with three or more types of medication simultaneously. The HAART treatment protocol has been a major factor in enhancing patient lifespans and overall quality of life, particularly in developed countries. HAART demands a permanent prescription for one or more drugs, and some HAART regimens may have significant negative consequences. People who take multiple medications may develop a tolerance to their effects over time. The fact that there is currently no comprehensive cure highlights the necessity of continuing research into cutting-edge medicines for HIV/AIDS.

HIV Basic

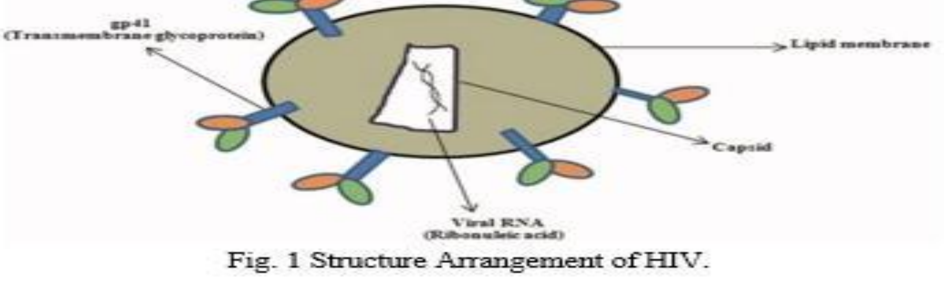

Fig. 1 Structure Arrangement of HIV.

The identification of HIV's causative agent in 1983 has resulted in significant efforts to understand its biology, which has led to the development of currently available therapeutic and preventative strategies [14]. It is clear that understanding the transmission process and pathogenesis of HIV infection is crucial for providing crucial insights into the development of new and better treatment options, as well as providing researchers with important tools Nanotechnology, a relatively new field of science and engineering, is already making significant contributions to various aspects of healthcare. This field encompasses the knowledge, skills, and practice necessary to work with atomic and molecular materials and structures. In nanotechnology, structures with a size of several hundred nanometres are feasible. Nanomedicine, which is also known as the medical use of nanotechnology, involves using very small materials to prevent, treat, and diagnose. Nanomedicine has made significant improvements over the past few decades, with a focus on cancer detection and treatment. Preventing and treating HIV/AIDS has been helped by nanotechnology in the past few years, but at a less advanced level. By developing new applications, nanotechnology has the potential to enhance existing treatments and develop new ones, including gene therapy and immunotherapy. In addition, certain nanomaterials are capable of being used as medicines by themselves. The production of vaccines and microbicides could have a significant impact from nanotechnology. Our study explores how nanotechnology can be utilized to enhance current therapies, develop new therapies, and provide alternatives for producing HIV/AIDS vaccines and microbicides.

Treatment options: Current HIV/AIDS Treatment

Therapy was introduced with antiretroviral drugs in the late 1980s and early 1990s. The late 1990s brought forth the concept of highly active antiretroviral therapy (HAART) which consisted of intensive combination drug regimens following the rapid development of antiretroviral resistance in individuals treated with single drug regimens. The use of HAART spread widely, resulting in a significant increase in life expectancy and quality, and turning AIDS from a rapidly progressing to a chronic disease.

HAART is the most advanced method of treating HIV/AIDS at present. Antiretroviral drugs are taken by patients simultaneously in amounts of three or more. It is common for medications from different classes to work differently when used together. While there has been a lot of progress in HAART therapy for HIV/AIDS, there are still some problems that need to be dealt with. The main obstacle has been the therapy's ineffectiveness, which is often due to patients' inability to adhere to their obligations. Patients don't adhere to the treatment plan because they are required to take the medication daily for the rest of their lives. If the body is not receiving enough medicine, the virus will start to reoccur.

Some individuals who adhere to their treatment plans can develop resistance to certain treatment combinations to the virus. HIV-1's enormous genetic diversity and constant change are the primary reasons why it is so challenging to treat. Providing each patient with a personalized treatment plan is the solution to this problem. Resistance testing is employed to select the most effective medication combination for each patient in this plan. The toxicity of drugs has the potential to cause harm and is a concern. HAART has been claimed to increase the likelihood of developing heart disease, diabetes, liver disease, cancer, and rapid aging in patients. It is common opinion among experts that HIV or co-infection with another virus, such as hepatitis C virus co-infection, may be responsible for these symptoms. These side effects may be a result of the toxic nature of the HAART drugs.

The virus has not yet been completely eliminated with our current therapy methods. Memory CD4+ T cells, as well as macrophage and monocyte progeny cells, have a place in which the virus has latent reservoirs. Macrophages have been widely acknowledged as latent repository of viruses for a long time, but recent research has revealed that they also play a crucial role in the generation of novel, difficult-to-detected mutant viral genotypes. HIV cells that are latent tend to hide in secondary lymphoid tissues, testes, liver, kidney, lungs, gut, and central nervous system. In order for long-term HIV/AIDS treatment to be successful, the virus must be eradicated from these sources. It is urgent to look into innovative methods to develop nontoxic, low-dose therapy strategies that can provide continuous dosing coverage, effectively eradicate viral reservoirs, and eliminate the need for life-threatening treatments.

Antiretroviral drugs for HIV/AIDS are being delivered using nanotechnology

The distribution of pharmaceutical medicines has undergone a technological revolution thanks to nanotechnology. Nanotechnology's primary objective is to modify a molecule's pharmacokinetics to make it effective in eradicating HIV. When an anti- HIV drug is encapsulated in a nano-system, its pharmacokinetics (how quickly and how far the drug travels in the body), pharmacodynamics (how well it works in the body), and physicochemical properties (particularly the size and molecules that are exposed to the surface) are all regulated by the nano-system (Li and Huang 2008, LaVan et al. 2002). Nanotechnology's use to deliver ARV drugs has great potential to alter the distribution of medicines across tissues and prolong HIV reservoirs' half-lives, which could have a positive impact on HIV treatment (Amiji et al.). 2006).

Nanoparticles

The word nanoparticles comes from the Latin term nanoparticles, which describe solid colloidal particles that range in size from 10 to 1 billionths of a millimeter. Their ability to deliver medications accurately and for an extended period is based on their colloidal size and polymeric composition, which play a crucial role. Polymeric nanoparticles, solid lipid nanoparticles, nanostructured lipid carriers, and inorganic nanoparticles are the most frequently used nanoparticles in HIV therapy. In order to overcome problems with drug formulation, such as poor stability and solubility, nanoparticles are being investing Research is currently underway on the delayed drug release kinetics of ARVs and how to deliver more accurately to HIV-infected cells.going. Drug encapsulation into these systems can result in improved efficacy, lower resistance, lower dosage, less systemic toxicity and side effects, and better patient compliance

Polymeric Micelles

Nanostructures that are less than 100 nm wide are known as polymeric micelles. Their use has enabled the drug molecules to improve their ability to target specific disease sites, travel through the digestive system, and dissolve in water. The core-shell structure of polymeric micelles, which are composed of block polymers, resembles that of surfactant micelles. Shell bricks are more prone to hydrophilicity than core blocks. Polymeric micelles have several benefits, including the ability to dissolve medications that are not easily soluble in water, chemical deterioration resistance, and controlled release

Fig. 2 Nanotechnology based Systems for HIV/AIDS Treatment.

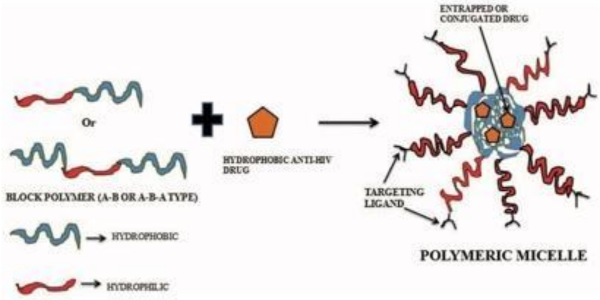

Fig. 3 Targeting of anti-HIV drug by Polymeric Micelle.

Antiretroviral Therapy

HIV patients have the option to select from more than 25 anti-retroviral medications in at least six different molecular classes. Reverse transcriptase inhibitors, whether nucleoside or not, are among the many compounds that can inhibit proteases or fusion proteins, as well as integrase strand transfer inhibitions. Due to the inability to eliminate viral reservoirs, none of these medications are curative, and the current goal of therapy is to provide lifetime treatment with lasting viral suppression. These problems could be reduced by the development or access to certain aspects made possible by the merger of pharmacology and nanotechnology.

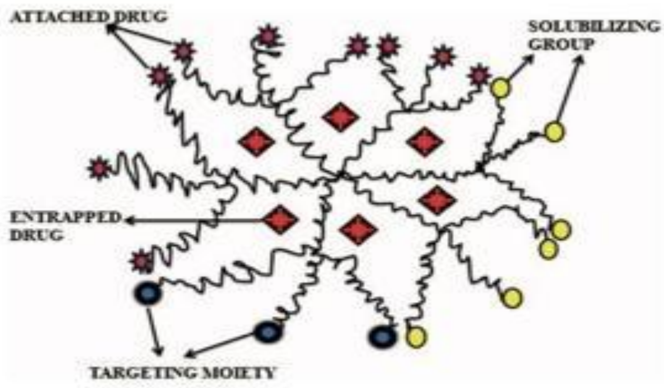

Fig. 4 Polymeric Dendrimers in anti-HIV drug targeting.

Conclusion

Nanotechnology has paved the way for new therapeutic options to be developed for the treatment of several devastating and complex diseases (e.g. In recent years, cancer and infectious diseases have been a major focus, leading to the release of several nanopharmaceuticals on the market. This manuscript confirms that nanotechnology-based systems can provide a logical strategy for treating and preventing HIV.

Potentially novel apprThe use of nanotechnology has the potential to lead to innovative approaches to HIV/AIDS thBy using nanotechnology platforms to deliver antiviral drugs, current treatment options may be enhanced. Improved therapeutic effectiveness could be achieved by increasing patient adherence to prescribed medication schedules, which can be achieved through controlled and prolonged release of pharmaceuticals. In the future, antiviral reservoirs may be treated more efficiently with the use of a nanoparticle delivery system that delivers multiple drugs simultaneously. The development of nanoparticles that can simultaneously deliver hydrophobic and hydrophilic medications or genes is being done by researchers from our group and another group, which could offer delivery options for antiviral drugs. Inhibiting viral replication has been demonstrated by nanomaterials, and this is in addition to their use in antiviral drugs. Gold nanoparticles, like silver nanoparticles, fullerenes, and dendrimers, are all capable of fighting viruses or can enhance antiviral effects of other compounds. The use of nanotechnology could enhance current therapeutic approaches, including gene therapy and immunotherapy. Nanotechnology research involves the nonviral dissemination of siRNA, which is one of the most active areas. Although there is still work to be done to create a safe and effective nanotechnology for RNA interference (RNAi) that can be used to treat HIV/AIDS, delivering siRNA to HIV-specific cells is now achievable. Immunotherapy, another important area, has the potential to be significantly impacted by nanotechnology. Nano immunotherapy, which is under investigation with the DermaVir Patch in Phase II clinical tests, has the potential to become the initial nanotechnology-based treatment for HIV/AIDS. In order to achieve nanotechnology-based solutions for HIV/AIDS, it is crucial to take into account the economic aspect, as the most seriously afflicted and sensitive individuals are from underdeveloped and economically deprived countries. Due to nanotechnology, the cost of antiretroviral therapy may increase, leading to a decrease in its overall value. Despite their higher cost than conventional treatments, nano-therapeutics could have a significant benefit in improving patient adherence by reducing the number of treatments administered and eliminating viral reservoirs, resulting in sterile immunity. Nanomedicine has the potential to lower the costs of developing and implementing innovative treatments like gene therapy and immunotherapy. The cost of nanotherapeutics shouldn't be higher than that of existing methods, particularly when it comes to preventive medicine. A cost-effective approach to combating the worldwide HIV/AIDS epidemic could be the development of nanotechnology-enhanced vaccines, since government organizations distribute huge quantities of immunisations extensively. To effectively distribute microbicides enabled by nanotechnology in economically challenged regions, it may be necessary to seek further help from government or non-governmental entities. In general, scientific discovery is moving at an unprecedented rate, and this is particularly true in the field of nanotechnology. It is widely agreed upon that investing in nanotechnology will yield long-term benefits for medicine and the HIV/AIDS industry

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