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Past, Present, and Future of Nanomedicine

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Outline

The Past

Nanomaterials have been evolving since the Greek times, they were found in the cup, but almost 64 years ago, they were named nanomaterials, due to their dimensions in nano-scale range. Nanomaterials were first synthesized using physical and/or chemical protocols, but with development, it was found that these methods were energy-consuming, expensive, and toxic. There are two methods, basic, that were employed to reach the nanoscale, Top-Down and Bottom-Up. Although with both the methods nanoscale could be reached but due to toxicity biochemical methods were highly appreciated. With the use of plant extracts and microbes, the synthesis of nanomaterials became easier and have been vastly employed, in current trends, and their use for medicinal purposes, i.e., anticancer and neurodegenerative diseases besides their potential use for anti-bacterial and antifungal potential. i.e., Adnan, W. G., and group synthesized Chromium Oxide (Cr_2O_3) nanoparticles using aqueous extract of lemon in water. The size of nanoparticles was measured to be 19.64 nm on average. The group further analyzed the biosynthesized Cr_2O_3 NPs using various techniques XRD, SEM, EDS, and TEM. The synthesized nanoparticles showed quite crystalline nature and were spherical. The group further analyzed the attachment of functional groups from lemon extract onto nanoparticle surfaces using FTIR. The group found various functional groups that played their part in the synthesis of nanoparticles. Furthermore, for the bio-medicinal properties, the group analyzed biomedical properties including anti-bacterial properties and anti-cancer potential against A549 lung cancer cell lines. The group found that at 100 µg/mL concentration against A549 cell lines showed %inhibition of 80% of cancer cell lines after 24 hours of incubation with Cr_2O_3 NPs. Whereas, in the case of anti-bacterial properties, the Cr_2O_3 NPs generated almost around 22.5mm of Zone of Inhibition (ZOI) against the Gram-Positive *S. mutans* bacterial strain [1].
With that, there have been establishment of various government bodies that could monitor the progress and study their safety sheets to find if the nanomedicines could be used or not. An example of such bodies is United States Food and Drug Authority (U.S. FDA).

The Present

With the evolution of nanotechnology, scientists moved from using naked, unfunctionalized nanoparticles for their bio-medical properties to their surface functionalization and drug loading. The use of techniques for surface functionalization and drug loading came into interest because of the potential toxicities and limitations that naked nanoparticles were facing, for their evolution from lab tests to animal tests. The limitations and toxicities included the nanoparticle's possible accumulation inside various vital organs, to toxicities like cell, genetic, muscle, and organ toxicity. The issues of toxicities and accumulations could be avoided by using lower nanoparticle concentrations, and when a nanoparticle is surface modified, it becomes target-specific and drug loading additionally provides them to use their lower concentrations for their applications. But the issues, even with lower concentrations, remain the same. The behavior and fate of nanoparticles inside a living cell are still unknown, therefore, a lot of studies are required to find the toxicities and other issues. Furthermore, to avoid the toxic effects of metal-based nanoparticles for medicinal purposes, currently various bio-polymeric nanoparticles are also being researched for their uses. Various studies have replaced

metal-based nanoparticles with two methods, either by using polymeric and metals in hybrid mode or by completely using polymeric nanoparticles.

For example, Norouzi, M., and group synthesized Iron Oxide nanoparticles IO NPs loaded with Doxorubicin (DOX) and trimethoxysilylpropyl-ethylenediamine triacetic acid (EDT) and studied their anti-cancer potential against U251 glioblastoma multiforme (GBM). The group reported that the size of DOX loaded IO NPs was almost 51.8 nm and studied the nanoparticles for their physical and chemical characteristics using TEM and FTIR. The nanoparticles were found to be spherical in shape furthermore, the FTIR confirmed the attachment of EDT and DOX onto nanoparticle surface. The group further found that the nanoparticles loaded with DOX and EDT-DOX were quite toxic towards the tested U251 cell lines. It can be seen from the IC_{50} values calculated for the synthesized nanoparticles, and for DOX loaded nanoparticles was found to be 300 ng/mL. Figure 8.1 shows the TEM images of nanoparticles uptake by U251 cells after 4 hours if exposure (figure adopted from [2], published under open access, Creative Commons (*CC*) License).

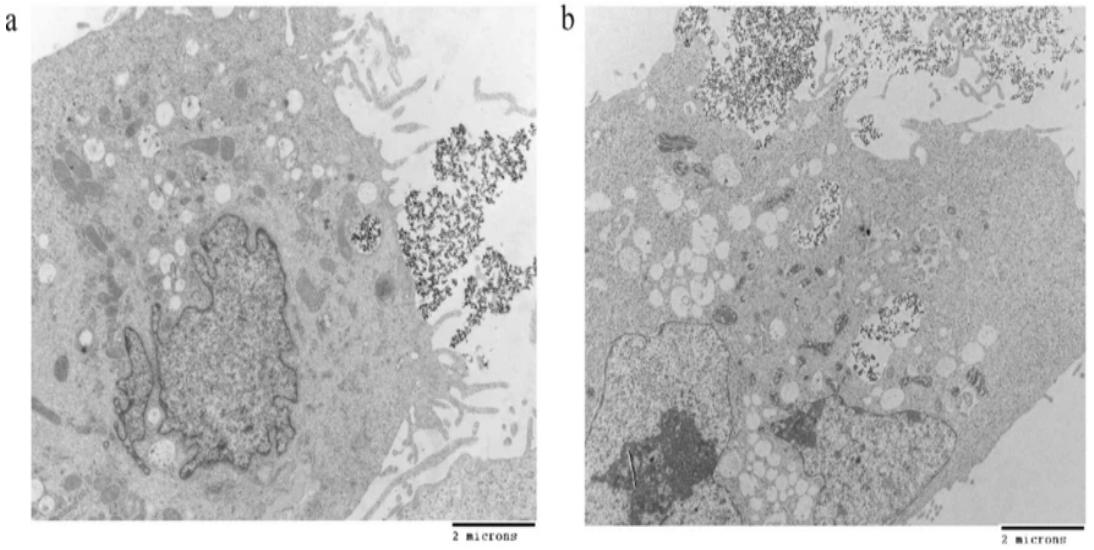

FIGURE 8.1
Cellular Uptake of nanoparticles by U251 after 4 hours of exposure. (a) EDT-IO NPs and (b) DOX-EDT-IO NPs. (Figure adopted from [2], published under open access, Creative Commons (*CC*) License).

Furthermore, Chaudhari, D., and research group PEGylated PLGA nanoparticles loaded with Paclitaxel (PTX) and Adenosine (ADN). The group calculated the nanoparticle size to be 135 nm on average and used the synthesized nanoparticles against 4T1 and MDA-MB-231 breast cancer cell lines and found them quite toxic against the tested cell lines, while the entrapment efficiency of nanoparticles was almost 80% of the drug introduced [3].

Although these loaded nanoparticles are being employed but there is still need of a lot of studies that could back the safety results.

The Future

Over the past few decades, the field of nanomedicine-based formulations has experienced extraordinary progress, representing a pivotal era characterized by substantial endorsements from esteemed regulatory bodies such as the FDA and EMA. This significant stride has elevated nanomedicines to the forefront of medical innovation, presenting a plethora of avenues to address complex and challenging diseases that span a broad spectrum—from cancer to respiratory and ocular disorders. The remarkable headway in nanomedicine signifies a paradigm shift in the approach to medical treatment. The multifaceted nature of nanomedicines lends itself to a versatile toolkit, offering potential solutions for diseases that were once considered daunting and difficult to manage. The wide-ranging applications, from combating cancer to addressing respiratory and ocular ailments, underscore the adaptability and potential impact of nanomedicine in diverse medical landscapes.

This progression not only holds promise for enhanced therapeutic options but also signifies a transformative era in medical science. The cumulative effect of these approvals and advancements is positioning nanomedicines as a beacon of hope for patients facing diseases with intricate complexities. The spectrum of conditions, including cancer, respiratory challenges, and ocular disorders, represents the diverse and dynamic battlefield where nanomedicine is proving to be a formidable ally.

In essence, the journey of nanomedicine from regulatory endorsements to tangible applications signifies a transformative era in medical research and treatment. It heralds a future where the once-daunting challenges posed by intricate diseases may find innovative and effective solutions through the pioneering advancements in nanomedicine-based formulations. Within the commercial landscape, a diverse array of nanomedicine-based formulations has emerged, encompassing lipid-based, polymer-based, nanocrystals, inorganic nanoparticles, and protein-based nanomedicines. These formulations, representing a revolutionary paradigm shift, are reshaping the very fabric of disease treatment and wielding a substantial influence on the dynamics of the healthcare system. Yet, the sheer diversity of nanomedicine types integrated into these formulations introduces a layer of complexity that necessitates nuanced attention. Consequently, a robust imperative arises to address concerns pertaining to safety and efficacy, aligning with the meticulous guidelines articulated by regulatory authorities such as the FDA and EMA. The intricate nature of nanomedicine-based formulations underscores the critical importance of a comprehensive approach to ensure that the therapeutic benefits are optimally realized without compromising patient safety.

Moreover, this evolving landscape underscores the urgency for exhaustive studies that delve into the intricate characterization of nanomedicines. Rigorous exploration across preclinical and clinical dimensions, coupled with meticulous cost–benefit analyses, is a pressing need. These endeavors are crucial to unravel the full spectrum of nanomedicine attributes, enabling a more nuanced understanding of their potential and limitations. Drawing on insights gleaned from antecedent research, coupled with a forward-looking commitment to rigorous studies and unwavering adherence to stringent regulatory guidelines, nanomedicines are poised to transcend current limitations. In doing so, they hold the promise of emerging as a distinctive and transformative solution, addressing unmet clinical needs with a blend of safety, efficacy, and innovation that augurs well for the future of healthcare.

References

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