Multifunctional Magnetic Nanoparticles-A Promising Approach for Cancer Treatment

Abstract

Magnetic (iron oxide-Fe_3O_4/Fe_2O_3) Nanoparticles (MNPs) play a significant role in the treatment of cancer due to their unique physicochemical characteristics including superparamagnetic behavior. MNPs can be used as

i. Contrast agents in Magnetic Resonance Imaging (MRI);

ii. Heating agents in magnetic hyperthermia based cancer therapy.

Moreover, MNPs (after their encapsulation into polymers) can be used as smart drug carriers to transport therapeutic molecules effectively to the specific cancer sites for eradicating/inhibiting cancer cell activities locally. In addition, magnetic nanoparticles can be encapsulated into pH sensitive responsive polymers to release drugs in a precisely controlled manner in association with heat based drug release. This mini-review article provides the snapshot on the properties and/or application of MNPs in the treatment of cancer.

Keywords: Magnetic nanoparticles; Hyperthermia; Cancer cell; Contrast agents; Magnetic resonance imaging; Biomedical; Multi drug resistance; Hyperthermia Therapy; Cytotoxic drugs; Doxorubicin; Neel fluctuation

Mini Review

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Abbreviations: MDR: Multi Drug Resistance; MNPs: Magnetic Nanoparticles; MRI: Magnetic Resonance Imaging; MR: Magnetic Resonance; SPIO: Super Paramagnetic Iron Oxide; AMF: Alternating Magnetic Field; BBMNs: Bifunctional Bacterial Magnetic Nanoparticles

Introduction

Cancer is one of the leading causes of death in the world [1]. Despite significant advances in the treatment of cancer in recent decades, it is still difficult to eradicate. Many factors contribute to its resiliency such as Multi Drug Resistance (MDR), poor selectivity for cytotoxic drugs, nonspecific bio-distribution and risk of damaging healthy cell [2,3]. The pathogenesis of cancer involves the structural and quantitative alterations in cellular molecules that control different aspects of cell behavior.

Recently, nanotechnology (concerning particles and devices in the range of 1-100 nm dimensions) provides new opportunities in cancer therapy and diagnostics (theranostics). Nanoparticle based therapies have been shown to

1. Diagnose the tumors precisely;
2. Reduce systemic toxicities and
3. Improve therapeutic efficacy of drugs [4].

Among various nanoparticles, Magnetic Nanoparticles (MNPs, particularly superparamagnetic iron oxide nanoparticles-Fe_3O_4/Fe_2O_3) are very prominent since they have unique physicochemical properties such as high magnetic saturation, bio-compatibility and excellent heating ability (when exposed to an Alternating Magnetic Field (AMF)) [5,6]. MNP-based Magnetic Resonance (MR) imaging with substantial signal enhancement can be utilized to locate the tumors for their early diagnosis [7]. Moreover, the AMF based induced heating effect (42-45 °C) of the MNPs can be efficiently used to inhibit the actions of cancer cells or to kill them locally, which is called as magnetic hyperthermia therapy [8].

The induced heating could be due to Neel and Brownian relaxations of MNPs in an aqueous environment. The extensively researched SPION in MRI is ferumoxtran-10, owing to its superior paramagnetic signals at low doses [9-12]. Moreover, they are also utilized in detection of metastasis of small lymph nodes and also in generation of heat under an AMF to induce death in different cancer cells. Thus, the integration of theranostics, by combining simultaneous Magnetic Resonance Imaging (MRI) and magnetic hyperthermia into a single nano-formulation via MNPs, has gained increased interest for researchers to ensure the optimal strategies for *In Vivo* cancer treatments.

Recently, MNPs based drug delivery system has gained high attention as an effective tool in cancer therapy, since it is capable of delivering the chemotherapeutic drugs into the cancer-specific site with fewer side effects as compared to the traditional delivery techniques [13]. Apart from that, cancer specific antibodies/targeting molecules (such as folic acid) can be functionalized onto the surface of the MNPs to target the cancer cells specifically to improve the therapeutic efficacy in cancer treatments [14]. Moreover, MNPs can also be functionalized with pH responsive polymers to improve the efficiency of drug delivery system, since the pH of the tissues is not constant throughout the body and it varies from tissues to tissues. For example, Zheng et al. [15] developed the Bifunctional Bacterial Magnetic Nanoparticles (BBMPs-a pH sensitive and targeted drug delivery system) by coupling doxorubicin and a galactosyl ligand onto the membrane surface of the Bacterial Magnetic Nanoparticles (BMPs), where the targeted BBMPs showed higher therapeutic efficacy in HepG2 cancer cell lines [15].

Conclusion

Recent developments in nanotechnology made possible to synthesize high-quality MNPs for biomedical applications. Moreover, the improved tumor-targeting ability of MNPs is also crucial for their success in cancer treatment. However, there is a need for better understanding of the interaction between the as-synthesized/encapsulated MNPs and the surroundings for designing smart drug delivery systems to achieve effective cancer theranostics. Furthermore, the other considerations, while designing the drug delivery systems it should also include the type of cancer, the micro-environment around the cancer sites. The mode of interaction with non-targeted organs and the fate of these formulated MNPs based nano-systems in different physiological environments.

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