Magnetic Nanoparticles in Drug Delivery: An Overview of Properties, Toxicity, and Future Applications

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Abstract:
Magnetic nanoparticles (MNPs) are attracting considerable interest as a tool for drug delivery and cancer therapy. The unique physical and chemical properties of MNPs make them ideal for targeted delivery of therapeutic agents to specific sites within the body. MNPs have a magnetic core that can be directed to the vicinity of the target using external magnetic fields, and they can also be functionalized with specific recognition moieties to target specific cells or tissues. In addition, MNPs can also be used for hyperthermia or for temperature-enhanced release of the drug, making them a versatile platform for cancer therapy.[1, 4, 5, 6].

MNPs can be synthesized in a variety of shapes and sizes and can be functionalized with a range of polymers, lipids, or proteins to impart specific properties, such as biocompatibility, biodegradability, and targeting specificity. The surface of MNPs can also be modified to reduce toxicity and improve stability. The large surface area-to-volume ratio of MNPs can lead to unfavorable biological responses if they are inhaled or swallowed and absorbed via the lung or gastrointestinal tract, respectively. Therefore, toxicity studies are an important aspect of MNP development and must consider not only acute toxicity but also the toxicity of degradation products and the long-term effects.[2, 3, 7, 19, 18, 24].

MNPs have been used as drug delivery vectors and for hyperthermia/thermal ablation. Magnetic drug delivery constitutes a promising technology for the treatment of cancer, and several products are already on the market. The limitations of external magnetic fields can, in some cases, be overcome by using internal magnets located in the proximity of the target through minimally invasive surgery. Magnetic fluid hyperthermia/thermal ablation is also a promising application, but it is limited by the need to localize the tumor.[8, 9, 10, 11, 12].

The greatest therapeutic potential of MNPs is likely associated with applications involving ‘intelligent’ particles that have a magnetic core, a recognition layer, and a therapeutic load. The challenges in this area include the development of suitable recognition moieties that can be attached to the particles and loaded to a high density while maintaining their desired properties.[13, 14, 15, 16, 17, 19].
In addition to drug delivery, MNPs have numerous other biomedical applications, including contrast agents for MRI, cell sorting and targeting, bioseparation, sensing, enzyme immobilization, immunoassays, and gene transfection/detection systems\cite{20}\cite{21}\cite{22}\cite{23}. Despite the promise of MNPs for cancer therapy, there is still much to be done to fully realize their potential, particularly with respect to improving the targeting specificity, biocompatibility, and toxicity profile of MNPs. Nevertheless, the development of MNPs for drug delivery and cancer therapy remains an exciting and rapidly evolving field with significant potential for improving patient outcomes.

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