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Review Article

Brain Cancer Diagnosis and Therapy Using Nano-Inspired Smart Medications

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Abstract

Nanomedicine advancements have aided in the advancement of cancer diagnostic and treatment results. However, due to unique constraints such as non-targeted dispersion resulting in low signal-to-noise ratio for diagnostics, difficult production, reduced biocompatibility, decreased photo stability, and systemic toxicity of nanomaterials within the body, regular usage of nanomaterials remains hard. Better nanomaterial-systems with regulated physicochemical and biological characteristics are thus required (Ozer et al., 2008). Smart nanomaterials are a possible option in this area since they may be triggered by specific external or endogenous stimuli such as pH, temperature, enzymes, or a specific biological molecule. The features of smart nanomaterials make them great candidates for a variety of applications such as biosensors, controlled medication release, and disease therapy. Smart nanomaterial-based cancer theranostic procedures have recently been developed, and they show superior selectivity and sensitivity with fewer side effects than conventional methods. In cancer therapy, the smart nanomaterials-system only activates in reaction to the tumor microenvironment (TME) and stays inactive in normal cells, reducing side effects and systemic toxicity even more (Wahab et al., 2008). As a result, the purpose of this study is to discuss the stimulus-based classification of smart nanomaterials, tumor microenvironment-responsive behavior, and their current applications in cancer theranostics. Furthermore, the current study discusses the advancement of several smart nanomaterials and their benefits in cancer diagnosis and treatment. We also talk about drug targeting and sustained drug release from nanocarriers, as well as the many types of nanomaterials that have been produced for this purpose (Kingsley et al., 2016).

INTRODUCTION

The brain is the most vital and amazing three-pound organ protected within the skull that is responsible for regulating memory, sensitive motor functions, and many other processes. It is made up of the cerebrum, cerebellum, brain stem, and four lobes (frontal, parietal, occipital, and temporal). The cerebellum is the biggest component of the brain, accompanying the right and left hemispheres and performing higher sensory and motor activities as well as directing motions; it is functionalized for muscle, posture, and movement coordination, and it is accompanied by the cerebrum. The cerebellum and cerebrum, however, are linked to the spinal cord via the brain stem, which is positioned underneath the cerebrum (Brown et al., 2015). It has a lot of automated functions. Furthermore, the important four lobes of the brain are associated with the appropriate propagation of behavioral processes. However, any abnormality in the physical structure of the brain, as well as unregulated cell proliferation, causes disturbance in the brain's regular functioning capacities. According to the National Brain Tumor Society, roughly 78,000 persons are diagnosed with malignant brain tumors in the United States each year, with 16,616 dying. Mass cell abnormal proliferation can be both static and metastatic, leading to the formation of both benign and malignant malignancies. Increased intracranial pressure, headaches, vomiting, altered consciousness, and seizures are all symptoms of a brain tumor. Furthermore, brain tumors may be further refined and categorised based on their development and placement inside the different brain cells (Haratym-Maj 2002).

Glial cells in the brain are the most prevalent location of brain tumor invasion. According to WHO criteria, brain glial cells are further categorized into four categories (grades 1–4). Grades I and II are considered low-grade cancers, whereas grades III and IV are considered higher-grade tumors. Adults are more likely than children to get metastatic brain tumors. Furthermore, lung cancer in men and breast cancer in women both spread to the brain. The etiological origins of brain cancer are yet unknown. Treatment of metastatic brain cancer (tumor) necessitates critical pharmaceutical characteristics such as non-chemotherapeutics, chemotherapeutics, radiation, and surgical procedures (Van et al., 2008). To treat tumor-related headache and epileptic seizures, non-chemotherapeutic medicines are preferable. Chemotherapeutic medicines, on the other hand, serve to reduce tumor bulk and edema while also eliminating cancer cells. Radiation therapy, on the other hand, may be used to avoid the bulk of brain tumors by using precise, concentrated beams that target the tumor while sparing the surrounding brain. Along with radiation therapy, a combination of four medications (lomustine, temozolomide, procarbazine, and vincristine) was administered. However, combining all therapies for brain cancer is extremely difficult since the blood-brain barrier (BBB) provides a significant barrier to effective medication distribution into the central nervous system. Furthermore, due of its complicated anatomical structure and physiology for central nervous system (CNS) protection, it is difficult to target for anti-cancer medications (Desai et al., 2008). The BBB is a key factor in maintaining the flow of essential electrolytes and cells between blood and the brain, in maintaining CNS homeostasis, and in protecting neural cells and tissues from pathogenic toxins. It is also selective in the uptake of certain drugs due to a lack of fenestrations for large-scale drug transport. Unfortunately, all therapies aimed to target brain tumors are difficult to develop and lack tailored delivery due to their huge size. Furthermore, the intricate structure of the BBB is attributable to unique brain mitochondrial cells, efflux transporters, and tight junctions, which reduces chemotherapeutic drug absorption and narrows the therapeutic window (Iniobong et al., 2019).

Correct diagnosis and numerous diagnostic tests for brain cancer, such as computed axial tomography (CAT scan/CT) with or without intravenous contrast, can help determine the prognosis of brain cancer. However, intraoperative magnetic resonance imaging (MRI) may be used to guide tissue samples and tumor removal during surgery. The chemical profile of the tumor is examined using magnetic resonance spectroscopy (MRS), and positron emission tomography (PET scan) is useful in identifying tumor recurrence. The diagnosis of brain cancer is difficult due to the large number of gaps that exist, in addition to over-testing, overdiagnosis, overtreatment, non-specificity, and the heterogeneous nature of brain cancer (Sudakin 2005).

The rapid advancement of nanotechnology for biological applications has had a significant influence on nanomedicine. Nanotechnology enables the synthesis and manipulation of materials at the nanoscale, aiding in the development of new instruments for the diagnosis, treatment, monitoring, and control of biological systems. Nanomaterials are described as a class of substances with any outward dimension at the nanoscale or with an internal or surface structure at the nanoscale, with sizes ranging from 1-100 nm. The use of nanostructured materials for drug administration to the brain is a promising technique because their nano-size allows them to readily penetrate the BBB and transport drug molecules to their target location. Various nanomaterials, including gold nanoparticles, liposomes, dendrimers, carbon nanotubes, and micelles, have been examined in connection to possible medication delivery to the brain (Chaudhry et al., 2014). Because NPs may overcome/mask the BBB's restrictive nature to drug molecules, drugs are efficiently transported to the brain. It is important to note that therapeutic chemicals or medications can be delivered to the brain at far lower concentrations than typical free drug dosages, allowing for safe drug delivery to achieve therapeutic efficacy. NPs exhibit more distinctive physicochemical features than bulk materials, including a large surface area, high drug loading, the capacity to include both hydrophilic and hydrophobic molecules, and great stability.

CONCLUSION

Tumors and cancers of the brain have a complicated pathophysiology that traditional imaging tools cannot detect. However, the development of nanotechnology has enabled the imaging of brain tissues with great resolution and sensitivity by actively targeting tumor cells. Several NPs have been created and manufactured to pass through the BBB and fulfill diagnostic and imaging functions. Nanomaterials have shown great promise due to their flexibility, biocompatibility, safety, and biodegradability. In this era of breakthrough discoveries, the use of nanoparticle probes for in vivo imaging and molecular profiling is a promising promise. However, given recent discoveries, safety issues must be addressed before considering clinical implications. This study outlines the present advancement of different nanomaterials, such as liposomes, nano-micelles, dendrimers, carbon nanotubes, carbon dots, and NPs (gold, silver, and zinc oxide NPs), in the treatment of brain cancer. The use of nanostructured materials for drug delivery to the brain is a promising technique since their nano-size allows them to readily penetrate the BBB and transport drug molecules to their target location. It is significant that therapeutic chemicals or medications may be delivered to the brain at far lower concentrations than typical free drug dosages, allowing for safe drug delivery to achieve therapeutic efficacy. However, before employing nanomaterials in medicine, particular features such as biodegradability, biocompatibility, water solubility, long shelf life, and prolonged circulation half-life should be well evaluated. Furthermore, the assessment of toxicity issues of

nanocarriers for clinical use is critical and must be carefully considered.

Smart nanotechnological solutions that have lately been created have the ability to overcome them. Despite preclinical animal trials demonstrating the immense promise of nanomedicine for the treatment of brain tumors, clinical human trial data has been less than adequate. The causes for this disparity are unknown, although the less-than-pronounced EPR effect and the variety of human brain tumors are thought to be key contributions. There is certainly still optimism, as well as plenty of space for development and optimization. Nanomedicines with improved pharmacokinetics and tumor deposition, for example, can avoid the variable ERP impact in people. Future avenues of study that may be advantageous for treating tumor heterogeneity (and treatment resistance) in human brain tumors include combinatorial techniques (simultaneous therapeutic and imaging; and numerous therapeutic agents) and personalized medicine (theranostics). The combination of imaging and therapeutic compounds into single nanoplatforms, in particular, may lead to major clinical results in treating brain tumors in a clinical context. Stimulus-responsive methods, particularly targeted ultrasound and magnetic field activation, may have the most therapeutic promise since they are neither tissue- or BBB-penetrating. Researchers across the world are already looking at these and other clever bioengineered solutions for better brain cancer detection, monitoring, and therapy. More research is needed, however, to assess (a) the efficacy of the combined approach (in comparison to separate studies of the therapeutic and imaging agents, as has been the case for most experimental models); (b) the optimization of brain tumor targeting across the heterogeneous cerebral vasculature; and (c) the non-specific toxicity and safety of nanomedicine in humans. We can only hope that next-generation nano-theranostics will meet the requirements of decreased toxicity, improved effectiveness, and long-term therapy for brain malignancies, bringing us closer to clinical success in neuro-oncology.

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