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Nanotechnology-Based Drug Delivery for Brain Tumours: Present Status and Future Prospects

Komal Rahevar, Tejas Prajapati, Mukesh Patel, Dhananjay Meshram

Pioneer Pharmacy College (Vadodara), India.

Email Id: serviceheb@gmail.com

ABSTRACT

Brain tumors, particularly gliomas, represent one of the most aggressive malignancies with high morbidity and mortality worldwide. Despite progress in surgical resection, radiotherapy, and chemotherapy, treatment outcomes remain poor due to several challenges, most notably the restrictive blood–brain barrier (BBB) and blood–tumor barrier (BTB), which severely limit drug accumulation at the tumor site. This has created an urgent need for innovative, targeted delivery approaches that can enhance therapeutic efficacy while minimizing systemic toxicity. This review highlights the most promising targeted drug delivery strategies for brain tumors. Key findings emphasize the potential of nanotechnology-based systems such as nanoparticles, liposomes, polymeric micelles, solid lipid nanoparticles, dendrimers, and inorganic nanocarriers, which offer improved circulation, controlled release, and tumor-specific accumulation. In addition, alternative routes and techniques including focused ultrasound-mediated BBB disruption, intranasal delivery, convection-enhanced delivery, and ligand-modified carriers have demonstrated significant potential in preclinical and translational studies. These strategies not only improve drug penetration into the brain but also open avenues for gene therapy, immunotherapy, and theranostics. In conclusion, precision-engineered targeted delivery platforms hold the potential to overcome current therapeutic limitations and pave the way toward more effective, safe, and personalized treatments for brain tumor patients in the future.

Keywords:

Brain tumor, Blood–brain barrier, Targeted drug delivery, Nanoparticles, Liposomes, Focused ultrasound, Intranasal delivery, Nanomedicine.

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