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Nanomaterials as Smart Drug Delivery Platforms in Cancer Therapy: Targeted Nanocarriers and Translational Advances

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ABSTRACT

Cancer chemotherapy is frequently limited by poor tumor specificity, systemic toxicity, rapid drug clearance, and suboptimal pharmacokinetics. Nanomaterial-based drug delivery systems have emerged as advanced therapeutic platforms designed to enhance tumor targeting, controlled release, and intracellular drug accumulation. Diverse nanocarriers, including liposomes, dendrimers, polymeric nanoparticles, nanoshells, metallic nanoparticles, and lipid-based systems, enable site-specific delivery through enhanced permeability and retention (EPR) effects and surface-functionalized targeting ligands. Smart nanocarriers improve therapeutic index by prolonging systemic circulation, enhancing cellular internalization, and enabling stimuli-responsive drug release triggered by pH, temperature, or enzymatic activity. These platforms reduce off-target toxicity while improving drug solubility and bioavailability. Emerging integration of nanoinformatics and machine learning further supports rational nanoparticle design, optimization of physicochemical properties, and predictive modeling of tumor-nanocarrier interactions. Although translational challenges remain including biocompatibility, large-scale manufacturing, regulatory approval, and long-term safety assessment, nanomaterial-based delivery systems represent a transformative strategy in oncology. Continued advancements in precision nanomedicine are expected to improve therapeutic outcomes and advance personalized cancer treatment paradigms.

Keywords: *Targeted nanotherapy, Stimuli-responsive release, Tumor microenvironment, Pharmacokinetic optimization, Nanoinformatics*

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