



Targeted Drug Delivery: Innovative Approaches for Precision Medicine in Cancer Treatment

Targeted drug delivery represents a groundbreaking approach in the field of precision medicine, offering significant

Despite the advancement, challenges remain in the widespread application of targeted drug delivery in clinical settings. The challenges include the stability of drug carriers, potential immunogenicity, and the heterogeneity of molecular targets in ongoing research and optimization. Nonetheless, the continuous evolution of targeted drug delivery technologies, coupled with a deeper understanding of cancer biology, offers promising pathways for a more effective and less toxic cancer treatment [4].

In conclusion, targeted drug delivery represents a significant leap forward in the quest for precision medicine in oncology. By focusing on drug delivery, the application of precision oncology, the approach aims to transform cancer treatment, providing new hope for patients and clinicians alike. As each progress is made, the potential of developing more effective and personalized therapies, including the application of gene therapy, molecular biology, and immunology, will be enhanced. The interdisciplinary collaboration of each patient's details.

2.2.2. Nanoparticle

Nanoparticle: Various types of nanoparticles, including liposomes, polymeric nanoparticles, gold nanoparticles, and dendrimers, are used. Nanoparticles are often used for commercial applications in the field of drug delivery and diagnosis.

In vivo Drug Conjugation (ADC): Specific antibodies are conjugated to cancer cells, and the conjugation is controlled. Commercially available ADCs, such as trastuzumab, are used for conjugation and in vivo drug delivery.

Cell Line: Human cancer cell lines, including breast (MCF-7), lung (A549), and colorectal (HCT-116) cancer cells, are used for drug delivery and cell uptake. Cell lines are maintained in DMEM or RPMI-1640 medium supplemented with 10% fetal bovine serum (FBS) and 1% penicillin-streptomycin [5].

Chemotherapeutic Agent: Drugs like doxorubicin, paclitaxel, and cisplatin are used as chemotherapeutic agents. They are evaluated for their efficacy in nanoparticle-conjugated drug delivery.

Targeting Ligand: Peptides and antibodies have specific binding to overexpressed receptors (e.g., HER2, EGFR) on cancer cells, leading to targeted drug delivery.

Buffer and Reagent: Phosphate-buffered saline (PBS), dimethyl sulfoxide (DMSO), and other reagents are used for drug loading, cell culture, and analysis of drug delivery [6].

2.2.3. In vivo

2.2.3.1. In vivo Drug Delivery and Evaluation

Synthesis of Nanoparticle: Nanoparticles are synthesized using methods like sol-gel, emulsion, nanoprecipitation, self-assembly, depending on the type of nanoparticle. Liposomes are prepared using the thin-film hydration method, followed by extrusion to achieve a narrow size distribution.

Drug Encapsulation: Chemotherapeutic agents are encapsulated in nanoparticles using passive loading or active loading techniques. Hydrophilic-lipid-polymer conjugates are used for drug delivery and encapsulation efficiency.

Characterization of Nanoparticle: Size, zeta potential, and polydispersity index (PDI) of nanoparticles are measured using dynamic light scattering (DLS). Morphology of nanoparticles is analyzed using transmission electron microscopy (TEM). Drug loading

efficiency and encapsulation efficiency are determined using high-performance liquid chromatography (HPLC) [7].

2.2.3.2. In vivo Drug Conjugation (ADC)

In vivo Selection and Conjugation: Antibodies are conjugated to cancer cells using an antigen (e.g., HER2, CD20) and an antibody-conjugated drug. Linkers are used to enable stable attachment and controlled release in target cells.

Precipitation and Validation: The ADC is precipitated using ethanol precipitation and validated for proper conjugation using SDS-PAGE and mass spectrometry. Binding affinity of the ADC to target receptors is confirmed using enzyme-linked immunosorbent assay (ELISA) [8].

2.2.3.3. In vivo Evaluation of Drug Delivery

Cell Uptake Study: To evaluate cell uptake of drug-loaded nanoparticles and ADCs, cancer cells are incubated with fluorescently labeled formulations. Uptake is analyzed using confocal microscopy and flow cytometry.

Cell Viability Assay: Cell viability is assessed using the MTT or CellTiter-Glo assay. Cell viability is determined by the concentration of the formulation, and the IC50 value is calculated to determine the dose-dependent efficacy.

Drug Release Study: In vitro drug release from nanoparticles is evaluated in PBS at pH 7.4 (mimicking physiological conditions) and pH 5.5 (mimicking acidic microenvironment). Release is measured at predetermined time points using HPLC [9].

2.2.3.4. In vivo Evaluation

Animal Model: BALB/c nude mice bearing human melanoma xenografts are used for in vivo efficacy studies. Tumor cells (e.g., MCF-7) are injected subcutaneously into the mice, and drug formulations are monitored until the end of the study.

Drug Administration: Mice are administered drug-loaded nanoparticles, ADCs, or control formulations intravenously. Dose and frequency of administration are optimized based on preliminary toxicity studies.

Biodistribution Study: To evaluate the targeting efficiency of the formulation, the biodistribution of fluorescently labeled nanoparticles is analyzed using in vivo animal imaging. Tissue samples are harvested and analyzed for drug concentration using HPLC.

Tumor Growth Inhibition: Tumor volume is measured using digital calipers over time, and the drug formulations' inhibitory effect is calculated. Histological analysis of mouse tissues is performed to assess apoptosis using TUNEL staining.

2.2.3.5. Statistical Analysis

Data are analyzed using GraphPad Prism software. All experiments are performed in triplicate, and the standard deviation (SD) is calculated. Statistical significance is determined using ANOVA followed by post-hoc testing, with a p-value < 0.05 considered statistically significant.

