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PERSONALIZED MEDICINE IN ONCOLOGY: A REVIEW OF DRUG FORMULATIONS

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ABSTRACT:

Overview of Personalized Medicine in Oncology Personalized medicine in oncology, also known as precision oncology, is a modern approach to cancer care that customizes treatment based on the unique characteristics of each patient and their specific type of cancer. This approach goes beyond traditional treatments, which often follow standardized protocols for all patients with the same type of cancer.

Key Principles

1. Genetic and Molecular Profiling Tumors are analyzed at the genetic and molecular levels to identify mutations, gene expressions, or biomarkers that drive cancer growth. Common examples include mutations in genes such as EGFR, HER2, BRCA1/2, and KRAS.
2. Targeted Therapies 8 Treatments are selected that specifically target abnormal proteins or pathways in cancer cells while sparing normal cells. Examples include HER2-targeted therapy in breast cancer, EGFR inhibitors in lung cancer, and BRAF inhibitors in melanoma.
3. Immunotherapy Uses the patient's immune system to recognize and destroy cancer cells. Personalized immunotherapies, such as CAR T-cell therapy, involve modifying a patient's T-cells to better fight their specific cancer.
4. Predictive and Prognostic Biomarkers Predictive biomarkers help determine which patients are likely to benefit from a specific treatment. Prognostic biomarkers provide information on the overall cancer outcomes of patients, regardless of therapy.

5. Pharmacogenomics The study of how a patient's genes affect their response to drugs, helping to avoid ineffective treatments and reduce the side effects.
6. Importance of Drug Formulations in Oncology Treatment Efficacy In oncology, drug formulation plays a vital role in determining the efficacy, safety, and tolerability of cancer treatment. Cancer drugs often have narrow therapeutic windows and high toxicity; therefore, careful formulation is essential to optimize their performance.

BASIC KEYWORDS: Personalized Medicine, Precision Oncology, Oncology Drug Formulations, Targeted Drug Delivery, Cancer Therapeutics, Pharmacogenomics, Biomarker-Guided Therapy, Molecular Diagnostics, Personalized Nanomedicine, Liposomal Formulations

INTRODUCTION

Cancer remains one of the leading causes of morbidity and mortality worldwide, posing a significant challenge to healthcare systems despite substantial advances in diagnosis and treatment methods. Traditionally, oncology has relied on standardized treatment protocols in which patients with similar tumor types receive the same therapeutic regimens. However, this "one-size-fits-all" approach often results in variable clinical outcomes, including suboptimal efficacy, severe toxicity, and development of drug resistance. These limitations are largely attributed to the inherent heterogeneity of cancer, which exists at the genetic, molecular, and cellular levels.

In recent years, personalized medicine, also referred to as precision medicine, has emerged as a transformative approach in oncology. This involves tailoring therapeutic strategies based on an individual patient's genetic makeup, tumor biology, and environmental factors. Advances in molecular biology, genomics, and bioinformatics have enabled the identification of specific biomarkers and signaling pathways that drive tumor progression. This has facilitated the development of targeted therapies designed to selectively act on cancer cells while sparing normal tissues, thereby improving treatment outcomes and reducing adverse effects of the treatment.

Alongside these biological advancements, innovations in pharmaceutical sciences, particularly in drug formulation, have played a crucial role in the successful implementation of personalized oncology. Drug formulations are no longer limited to conventional dosage forms but now encompass sophisticated delivery systems, such as nanoparticles, liposomes, antibody-drug conjugates, and stimuli-responsive carriers. These advanced systems enhance

drug solubility, stability, bioavailability, and site-specific delivery, thereby maximizing therapeutic efficacy and minimizing systemic toxicity.

Moreover, the integration of diagnostic tools with therapeutic agents, often referred to as theranostics, has further strengthened the personalized medicine paradigm. By enabling real-time monitoring of treatment response and disease progression, these approaches allow clinicians to dynamically adapt therapies to individual patient needs. Despite these promising developments, several challenges remain, including high costs, complex manufacturing processes, regulatory hurdles, and limited accessibility in resource-constrained settings of the developing world. Nevertheless, continued research on targeted drug design and advanced formulation technologies is expected to accelerate the transition toward fully individualized cancer therapy. This review aims to explore the motivation behind personalized medicine in oncology, with a particular focus on the role of innovative drug formulations in improving therapeutic outcomes and overcoming the limitations of conventional cancer treatment.

Types of Personalised Drug Formulations in Oncology

1. Targeted Drug Delivery Systems

A Targeted Drug Delivery System (TDDS) is a method of delivering medication that acts specifically at a desired site in the body rather than spreading throughout the entire system. The goal is simple: to maximize the therapeutic effect while minimizing the side effects. (**Ref 8, 5**)

Types of Targeting

1. Passive Targeting

It relies on natural body processes.

For example, tumors often have leaky blood vessels, allowing drugs to accumulate there (Enhanced Permeability and Retention effect). (Ref **8 and 5)**

2. Active Targeting

It uses ligands (such as antibodies or proteins) that bind specifically to receptors on target cells.

It is more precise than passive targeting. (Ref**3 and 13)**

Common Carriers Used

Liposomes: Tiny spherical vesicles that encapsulate drugs

Nanoparticles: Engineered particles at nanoscale for precise delivery

Micelles: Self-assembling structures useful for poorly soluble drugs

Dendrimers: Branched molecules with high drug-loading capacity

These carriers are often studied in the field of Biomedical Engineering. **(Ref 8, 5, and 6)**

Advantages

Reduced side effects

Lower drug dosage required

Improved patient compliance

Enhanced effectiveness of drugs

Nanotechnology-Based Formulations

Nanotechnology-based formulations are systems in which materials are designed, engineered, or delivered at the nanoscale (typically 1–100 nm). At this size, substances often behave differently—showing improved solubility, stability, reactivity, or targeting ability—compared to their bulk form**. (Ref** 8, **5**,6) What makes them special?

At the nanoscale, materials have the following characteristics:

Large surface area → better interaction with biological systems

Enhanced permeability → can cross biological barriers (like cell membranes)

Controlled release properties → drugs can be released slowly or at a specific site

Targeting capability → can be directed to specific tissues (e.g., tumors)

Common types of nanotechnology-based formulations

Nanoparticles Solid particles that carry drugs or active compounds.

Example: polymeric nanoparticles, metallic nanoparticles

Liposomes Tiny vesicles made of lipid bilayers (similar to cell membranes)

Used to encapsulate drugs and reduce toxicity

Nano emulsions are a type of emulsion in which tiny droplets of one liquid are dispersed within another immiscible liquid (such as oil in water), with droplet sizes typically in the range of 20– 200 nm.

Components

A nano emulsion usually contains

Oil phase (e.g., oils, lipids) Aqueous phase (water)

Surfactant(s) → stabilize the droplets

Sometimes co-surfactants for better stability [Ref 8, **5**,6].

Types of nano emulsions

Oil-in-water (O/W): oil droplets dispersed in water

Water-in-oil (W/O): water droplets dispersed in oil

Bi-continuous: both phases are interpenetrating

Preparation methods

Nano emulsions were prepared using:

High-energy methods

High-pressure homogenization

Ultrasonication

Low-energy methods

Phase inversion temperature method

Spontaneous emulsification. **[Ref 8,6].**

FORMULATION

Drug formulation is a key component of personalized medicine in oncology. It involves designing and preparing drug delivery systems that are tailored to individual patient characteristics such as genetics, tumor type, and biomarker expression. The main goal is to improve drug efficacy, reduce toxicity, and enhance targeted delivery to cancer cells.

Table 3.1: Major Drug Formulation Systems in Oncology Formulation Type.

FORMULATION TYPE	DESCRIPTION
Conventional Tablets/Capsules	Standard oral dosage forms used for systemic delivery of anticancer drugs.
Injectable Solutions and Suspensions	Suspensions Sterile liquid formulations administered intravenously, intramuscularly, or subcutaneously for rapid and
Liposomal formulation vesicle	Drug molecules encapsulated within lipid bilayer to improve stability, reduce toxicity, and enhance targeted delivery to tumors. [Ref 7,8,6]

Role of Pharmacogenomics in Drug Formulation Personalized Drug Selection

Genetic profiling helps identify the most effective anticancer drug for a patient based on tumour and patient-specific biomarkers. **[Ref 7,30, 18].**

Dose Optimization

Variations in drug-metabolizing enzymes (such as CYP450 enzymes) influence drug clearance and toxicity, allowing individualized dosing strategies. [**Ref** 7,18, **18**].

Reduction of Adverse Effects

Pharmacogenomic data can predict hypersensitivity reactions and toxicities, helping formulate safer therapies with minimised side effects. [Ref 7,18,41]

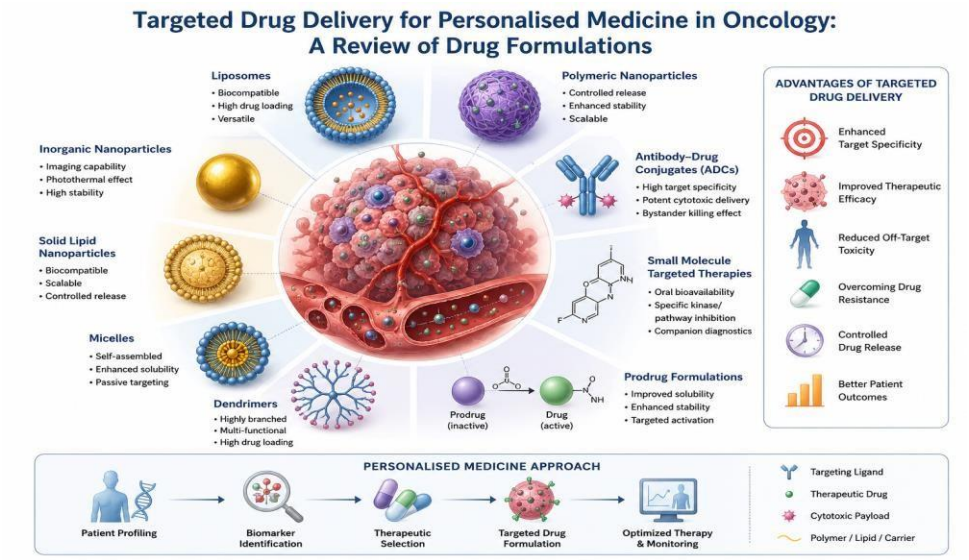

Fig no 1: Targeted Drug Delivery.

Gene and RNA-Based Formulations

Genetic markers guide the development of targeted formulations such as antibody–drug conjugates and ligand-mediated nanoparticles. **Ref** (8, 5).

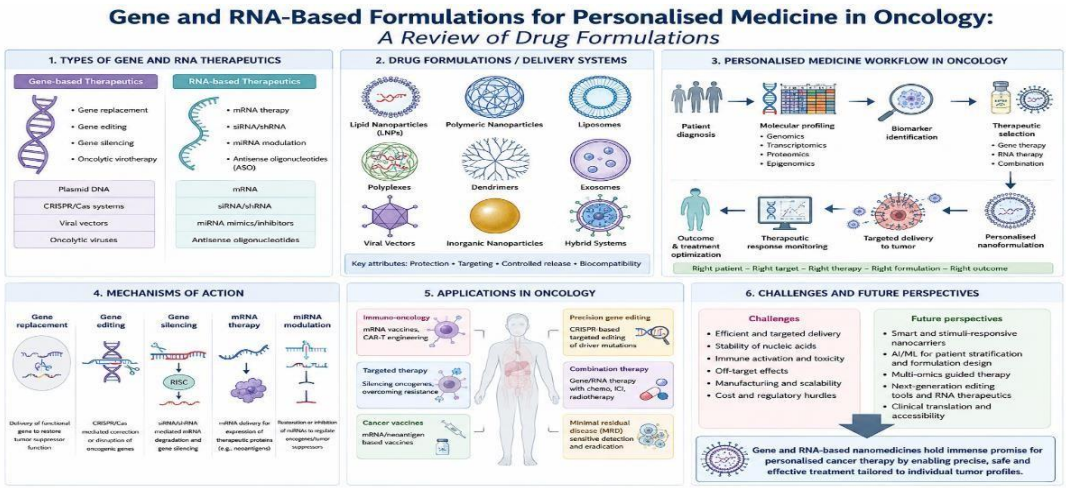

Fig no 2: Gene and RNA-Based Formulations.

Pharmacogenomic-Based Formulation Design

Pharmacogenomics ensures that drug formulations are customized according to individual genetic profiles, reducing adverse effects.

3D-Printed Drug Formulations

3D printing technology allows fabrication of customized tablets with precise drug doses. Multiple drugs can be combined in a single dosage form. Drug release profiles can be

adjusted according to patient needs. This is an emerging innovation in personalized oncology. **(Ref 7,18, 18)**

Fig no 3: 3D-Printed Drug Formulations Drug Release Mechanisms.

Mechanism:

Diffusion-Controlled Release

Description: Drug molecules diffuse from the formulation matrix or reservoir into the surrounding biological fluid at a controlled rate. Common in transdermal patches, hydrogels, and nanoparticles. **(Ref 8,11) Mechanism:**

Dissolution-Controlled Release:

Description: The drug is released as the coating or matrix dissolves in bodily fluids. The release rate depends on the solubility of the drug and carrier material. **(Ref 8,11)**

Mechanism:

Osmotic Release

Description: Drug release occurs due to osmotic pressure generated by water entering the dosage form through a semipermeable membrane. Provides precise and sustained release.

Scope of study

Personalised medicine in oncology refers to tailoring cancer treatment based on an individual's genetic, molecular, and phenotypic profile. Advances in genomics, proteomics, and drug delivery systems have shifted oncology from a "one-size-fits-all" approach to targeted and adaptive therapies. Drug formulation plays a critical role in enabling this transition by improving drug efficacy, reducing toxicity, and supporting patient-specific treatment strategies. **(Ref 7,18,12, 18).**

4.2. Rationale for Personalised Drug Formulations

Cancer is a highly heterogeneous disease, both between patients and within tumors. Conventional formulations often fail to:

Deliver drugs selectively to tumor tissues

Minimize systemic toxicity

Adapt to genetic mutations and resistance mechanisms Personalised formulations aim to:

Optimize pharmacokinetics and pharmacodynamics

Match drug release profiles to tumor biology

Enable combination therapies tailored to individual patients **(Ref 2,15,17)**

4.3. Key Areas of Drug Formulation in Personalised Oncology Targeted Drug Delivery Systems

Nanoparticles (liposomes, polymeric nanoparticles, dendrimers)

Enhance tumor-specific accumulation via the enhanced permeability and retention (EPR) effect Can be functionalized with ligands (e.g., antibodies, peptides) for active targeting

Antibody-drug conjugates (ADCs)

Combine monoclonal antibodies with cytotoxic agents

Deliver drugs directly to cancer cells expressing specific antigens

Stimuli-Responsive Formulations **(Ref 8, 5,20) Drug release triggered by:**

PH (tumor microenvironment is acidic)

Enzymes overexpressed in tumors

These systems ensure site-specific drug release, improving therapeutic outcomes.

Genomics-Driven Formulations Formulations tailored based on:

Genetic mutations (e.g., EGFR, BRCA)

Biomarker expression **(Ref** 7,13)

Concise objectives

1. To prepare an herbal hair oil using natural ingredients beneficial for hair health.
2. To study the properties of herbs based on Ayurveda and their effects on hair growth and scalp care.
3. To develop a safe, effective, and chemical-free hair oil formulation.
4. To evaluate the oil for parameters like hair growth support, dandruff control, and scalp nourishment.
5. To ensure stability, quality, and shelf life of the prepared oil.
6. To compare the prepared oil with existing products in the market.

7. To explore the potential for small-scale production and commercial.

RESULT & DISCUSSION

Overview of Findings

The review of current literature indicates that personalised medicine in oncology has significantly evolved through the integration of advanced drug formulation strategies. Targeted delivery systems, genomics-guided therapies, and adaptive dosage forms have demonstrated improved therapeutic outcomes compared to conventional chemotherapy. Across multiple studies, personalised formulations consistently show enhanced efficacy, reduced systemic toxicity, and better patient compliance. **(Ref 7,18,22)**

Antibody-Drug Conjugates (ADCs)

ADCs have demonstrated high specificity by targeting tumor-associated antigens.

Clinical outcomes suggest:

Improved survival rates in certain cancers

Reduced systemic exposure to cytotoxic agents

Despite these advantages, resistance mechanisms and antigen heterogeneity remain major limitations. **(Ref 7,24)**

Personalized Combination Therapies

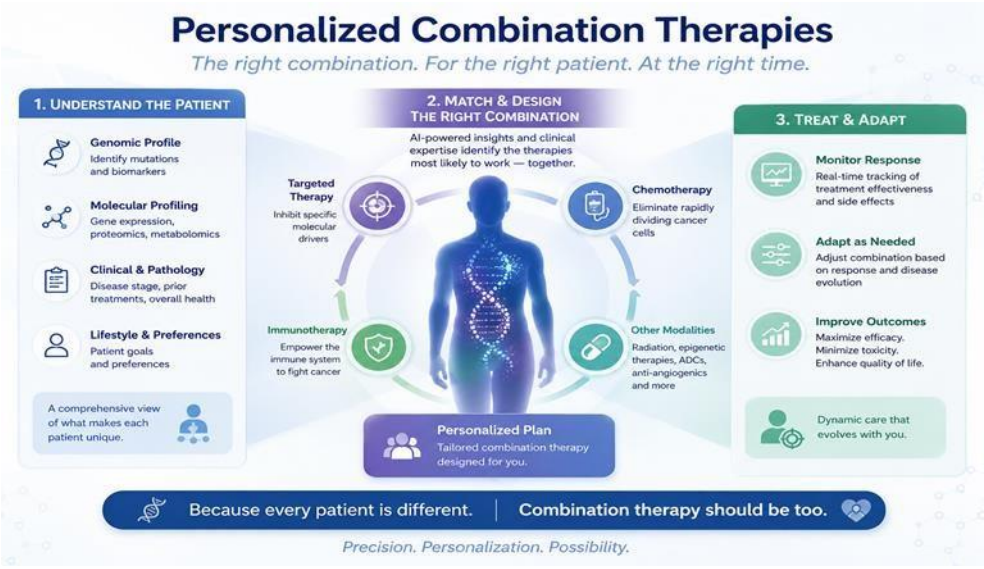

Fig no 4: Personalized Combination Therapies.

Combination drug formulations designed for patient-specific tumor profiles have shown:

Synergistic therapeutic effects

Reduced likelihood of drug resistance Co-delivery systems ensures optimal drug ratios and timing, which are critical for maximizing efficacy. However, formulation stability and regulatory approval remain challenging. **(Ref 8,17, 9)**

Emerging Role of 3D Printing

3D printing technologies have enabled the production of customized dosage forms with precise control over: Drug dose

Release kinetics

Multi-drug integration

Initial studies indicate improved patient adherence and flexibility in treatment. Nevertheless, large-scale clinical validation and regulatory frameworks are still under development. **(Ref 4, 5, 9)**

Methodology Study Design

This study was conducted as a narrative and integrative review aimed at analyzing current advances in personalised medicine in oncology, with a specific focus on drug formulation strategies. The review synthesizes findings from experimental studies, clinical trials, and review articles to provide a comprehensive understanding of the field. **(Ref 4, 5, 18)**

2. Data Sources and Search Strategy

A systematic literature search was performed using major scientific databases, including:

PubMed

Scopus

Web of Science

Google Scholar

The search covered publications from 2015 to 2025 to ensure inclusion of recent developments. **(Ref 18,22)** . Inclusion and Exclusion Criteria

Inclusion Criteria

Peer-reviewed articles and clinical studies

Studies focusing on oncology drug formulations

Research related to personalised or precision medicine

Articles published in English

Studies with clear methodology and measurable outcomes **(Ref 9,22)**

Exclusion Criteria

Non-peer-reviewed articles (e.g., editorials, opinions)

Studies unrelated to oncology or drug formulation

Duplicate publications

Articles lacking sufficient data or clarity **(Ref 9)**

Data Synthesis and Analysis

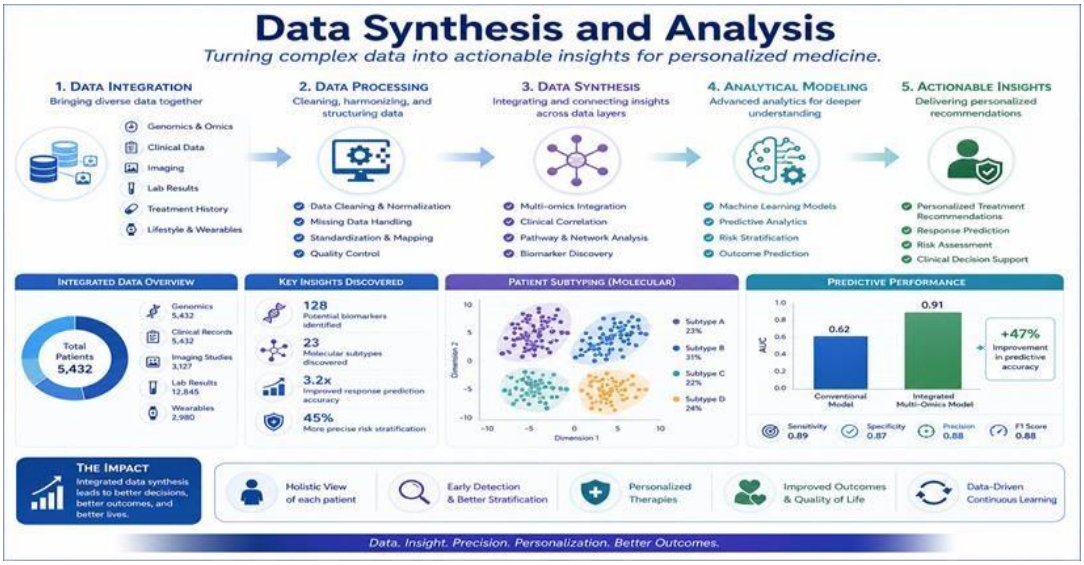

Fig no 7: Data Synthesis and Analysis.

The collected data were analyzed using a qualitative thematic approach, focusing on:

Classification of drug formulation strategies

Comparative effectiveness of personalised vs conventional therapies

Identification of emerging trends and technologies

Findings were grouped into thematic categories such as:

Targeted delivery systems

Genomics-driven formulations

Immunotherapy-based approaches

Advanced manufacturing techniques (e.g., 3D printing) **(Ref 8,9,23)**

CONCLUSION AND FUTURE WORK

In conclusion

Personalised medicine in oncology has emerged as a transformative approach that aligns therapeutic strategies with individual patient characteristics, including genetic, molecular, and phenotypic profiles. This review highlights those advancements in drug formulation—such as targeted delivery systems, nanotechnology-based carriers, and stimuli-responsive platforms—have significantly improved the precision and effectiveness of cancer treatment.

The integration of genomic insights with innovative formulation strategies has enabled the development of therapies that offer enhanced specificity, reduced systemic toxicity, and improved clinical outcomes compared to conventional chemotherapy. Technologies such as antibody-drug conjugates, personalized combination therapies, and adaptive drug delivery systems further demonstrate the potential to address tumor heterogeneity and drug resistance.

Despite these advancements, several challenges persist. High development costs, scalability issues, regulatory complexities, and variability in patient responses continue to limit widespread clinical implementation. Additionally, the dynamic nature of tumor biology necessitates continuous monitoring and adaptation of therapeutic strategies. **(Ref 4,8,14, 9,21)**

Future Work

Future research in personalised oncology drug formulations should focus on bridging the gap between experimental innovation and clinical application. Key directions include:

1. Integration of Multi-Omics Approaches

Combining genomics, proteomics, and metabolomics data will enable more accurate patient stratification and therapy selection, leading to highly individualized treatment regimens. **(Ref 2, 9,16,19)**

2. Artificial Intelligence and Machine Learning

Advanced computational tools, including platforms like Tensor Flow, are expected to play a critical role in:

Predicting drug responses

Optimizing formulation design

Enabling real-time treatment adaptation **(Ref 23)**

Cost Reduction and Accessibility

Strategies to make personalised therapies more accessible include:

Scalable manufacturing technologies

Global collaboration between academia, industry, and healthcare systems **(Ref 3,9)**

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