

Integrative Advances in Nanostructured Drug Delivery, Phytopharmaceuticals, Artificial Intelligence, and Supportive Care in Cancer and Metabolic Disorders

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ABSTRACT:

Rapid advancements in pharmaceutical sciences have reshaped therapeutic strategies for complex diseases such as neuroendocrine cancer, metabolic disorders, chronic inflammation, and neuropathic conditions. Innovations in nanostructured drug delivery systems, sustained- and delayed-release formulations, phyto-nanomedicine, biologics, and artificial intelligence (AI) have collectively improved drug targeting, bioavailability, safety, and personalization of therapy. Additionally, emerging insights into nutritional modulation, supportive nursing care, and prevention of medication errors have strengthened holistic disease management. This review integrates evidence from nanotechnology-based carriers, advanced oral dosage forms, phytopharmaceuticals, monoclonal antibodies, AI-driven pharmaceutical research, and clinical care perspectives, highlighting their translational relevance and future potential in precision medicine.

Keywords: *Nanostructured drug delivery, Neuroendocrine cancer, Sustained-release formulations, Phyto-nanomedicine, Artificial intelligence, Targeted therapy*

INTRODUCTION:

Neuroendocrine cancers (NECs) are a heterogeneous group of malignancies with variable biological behavior and limited responsiveness to conventional chemotherapy, presenting significant challenges in clinical management [1]. The complexity of these tumors, coupled with late-stage diagnosis and multidrug resistance, underscores the need for advanced therapeutic strategies. Nanostructured drug delivery systems have emerged as transformative tools, offering targeted drug delivery, improved bioavailability, and reduced systemic toxicity.

Simultaneously, advancements in oral drug delivery, including sustained- and delayed-release formulations and 3D-printed personalized dosage forms, have enhanced patient compliance and enabled precise modulation of pharmacokinetics [2,3]. Phytopharmaceuticals and phyto-nanomedicine have

demonstrated therapeutic potential in metabolic disorders, inflammatory conditions, and cancer, overcoming limitations of poor solubility and bioavailability through integration into nanocarriers [4,5,6].

Biologics, particularly monoclonal antibodies, have revolutionized targeted therapy, showing promise in autoimmune and oncologic applications [7,8]. The application of artificial intelligence (AI) in pharmaceutical research has further accelerated drug development, optimizing formulation strategies, predictive modeling, and clinical decision-making. Beyond pharmacotherapy, supportive care, including nutritional modulation, nursing interventions, and strategies to prevent medication errors, plays a critical role in improving therapeutic outcomes and patient safety. This review provides an integrative perspective on these advances, emphasizing translational relevance and the future potential of combined therapeutic and supportive strategies in precision medicine [9,10].

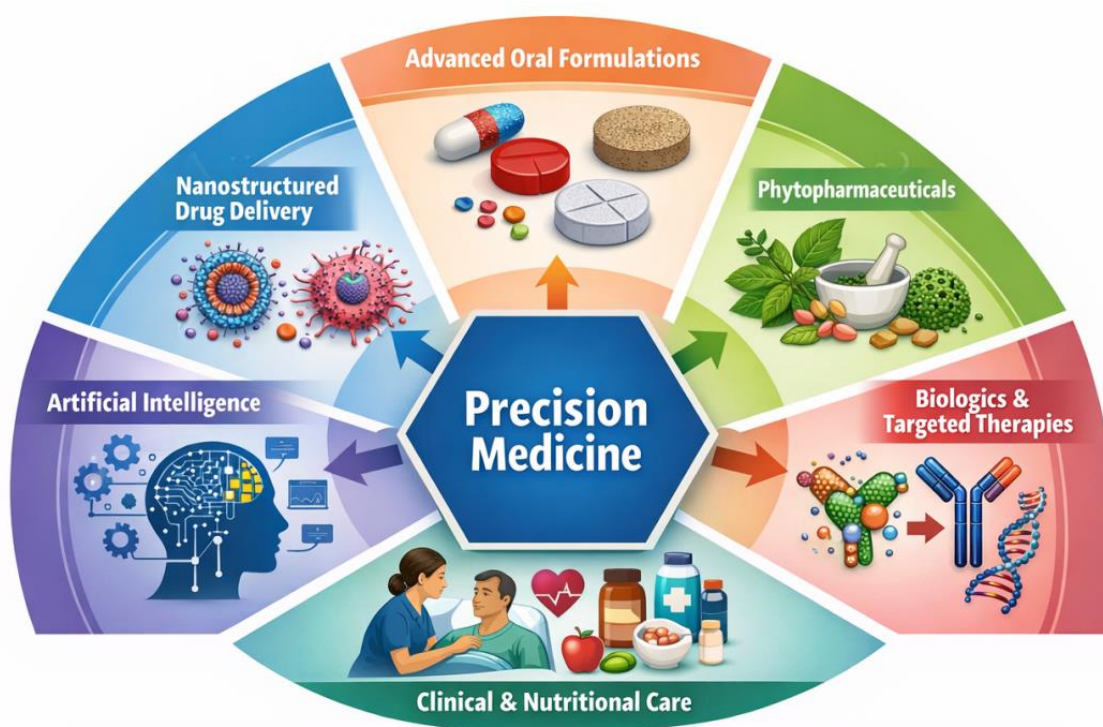


Fig.1: Integrative approaches for Cancer and Metabolic disorder Management

1. Nanostructured Drug Delivery Systems and Targeted Cancer Therapy:

Nanostructured drug carriers have emerged as transformative tools in cancer therapy, particularly for neuroendocrine tumors characterized by heterogeneity and limited responsiveness to conventional chemotherapy. Polymeric nanoparticles, lipid-based carriers, nanoemulsions, solid lipid microparticles, and nanogels enhance drug solubility, stability, and tumor-specific accumulation while reducing systemic toxicity [1,4]. These systems also play a crucial role in overcoming multidrug resistance and improving therapeutic indices. The application of nanotechnology has further expanded into antiviral, anticancer, and inflammatory disease management, reinforcing its versatility across therapeutic domains.

2. Advanced Oral Drug Delivery and Personalized Dosage Forms:

Oral drug delivery remains central to chronic disease management, and advances in formulation science have significantly improved therapeutic outcomes. Sustained-release matrix tablets enable prolonged drug release, improved glycemic control, and enhanced patient compliance, as demonstrated in antidiabetic therapies. Delayed-release formulations further allow site-specific drug delivery, minimizing adverse effects [11,12]. The advent of 3D printing technology has enabled

personalized medicine by facilitating patient-specific dosage forms designed using Quality by Design (QbD) principles, offering precise control over drug release and dosing. Tablet-in-tablet systems represent another innovation, allowing combination therapy and sequential drug release, particularly valuable in cancer treatment [13,14].

3. Phytopharmaceuticals and Phyto-Nanomedicine in Disease Management:

Phytoconstituents possess diverse pharmacological activities, including antioxidant, anti-inflammatory, antidiabetic, and anticancer effects. Advances in extraction and identification techniques have improved the standardization and therapeutic application of bioactive compounds from herbs and spices. However, limitations such as poor solubility and bioavailability have restricted their clinical translation. Phyto-nanomedicine, which integrates phytochemicals into nanocarriers, has effectively addressed these challenges, enhancing stability and therapeutic efficacy [13-15]. Experimental studies have demonstrated the protective role of bioflavonoid combinations in diabetes-induced nephropathy and other metabolic complications through modulation of key molecular pathways. Additionally, phytoconstituents have shown promising outcomes in inflammatory disorders, wound healing, psoriasis, and liver diseases [16-18].

4. Biologics, Targeted Therapies, and Emerging Anticancer Agents:

Biologics, particularly monoclonal antibodies, represent a cornerstone of targeted therapy due to their high specificity and immunomodulatory properties. Their application in autoimmune diabetes and oncology has demonstrated significant potential in disease modification and precision therapy. Advances in medicinal chemistry have further led to the development of novel targeted agents, including imatinib derivatives and next-generation EGFR inhibitors such as sunvozertinib, which offer improved efficacy in specific cancer subtypes [19]. The integration of biologics with nanocarrier systems may further enhance targeting efficiency and therapeutic outcomes.

5. Clinical, Nutritional, and Supportive Care Perspectives:

Effective disease management extends beyond drug development to include supportive clinical care, nutrition, and patient safety. Studies highlight gaps in oncology nurses' knowledge and attitudes toward cancer pain management, emphasizing the importance of education and multidisciplinary collaboration. Nutritional modulation has shown protective effects in conditions such as hepatotoxicity, metabolic liver disease, and hypertension, reinforcing the role of dietary interventions alongside pharmacotherapy. Additionally, addressing medication errors through systematic preventive strategies is essential to improve patient safety and therapeutic outcomes in clinical practice [20-22].

6. Artificial Intelligence in Pharmaceutical Research and Healthcare:

Artificial intelligence and machine learning have revolutionized pharmaceutical research by enabling predictive modeling, formulation optimization, virtual screening, and in-silico drug design. AI-driven approaches significantly reduce drug development timelines and improve decision-making in formulation and process optimization. Beyond research and development, AI has demonstrated substantial impact in healthcare systems through improved diagnostics, disease prediction, workflow optimization, and personalized treatment planning [12]. The convergence of AI with nanomedicine and advanced drug delivery systems is expected to play a pivotal role in the future of precision medicine.[23-25]

CONCLUSION:

The convergence of nanostructured drug delivery systems, advanced oral formulations, phytopharmaceuticals, biologics, artificial intelligence, and supportive clinical care has reshaped modern therapeutic paradigms. Evidence across cancer,

metabolic, inflammatory, and chronic disorders underscores the translational potential of these integrated approaches in achieving targeted, personalized, and safer treatments. Continued interdisciplinary research, coupled with AI-assisted innovation and patient-centric care, will be critical in advancing precision medicine and improving long-term health outcomes.

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