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# NANOMEDICINE CLINICAL ONCOLOGY CURRENT APPLICATIONS AND FUTURE DIRECTIONS

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## ABSTRACT

*Nanomedicine has revolutionized a clinical oncology as it was used to present a new form of in-target delivery of drugs, diagnostics, and immunomodulation. During the past three decades, lipid, polymer and inorganic nano systems have evolved to the levels of laboratory oddity, approved treatment and a number of clinical trials. It has demonstrated that nanoscale carriers could enhance pharmacokinetics and reduce systemic toxicity but not antitumor efficacy with clinical established formulations, such as pegylated liposomal doxorubicin and albumin-bound paclitaxel. It would later be possible to translate RNA therapeutics to oncology by one of the methods including the construction of lipid nanoparticles containing mRNA which can be tailored to create a personalized cancer vaccine and novel forms of cell therapy. Clinical translation has not realized the anticipated success and is still facing several obstacles including heterogeneity of tumour microenvironment, scale-up and production and complexity in regulatory processes. This review sums up the current clinical and translational literature, the status of approved clinically and in late-stage nanomedicines, failure modes ascertained by clinical trials, and the strategizing direction with a view to accelerate significant improvements on patient outcome. It is a hierarchical and multi-stage targeting strategy, which includes immunotherapies, RNA and other gene-editing delivery, improved design of biological barrier (e.g., the blood-brain barrier), and mild manipulation of regulatory pathways to encourage complex multifunctional nanotherapeutics.*

***Keywords:*** *Nanomedicine; oncology; liposomal doxorubicin; lipid nanoparticles; mRNA; targeted delivery; clinical translation; tumour microenvironment.*

## INTRODUCTION

Cancer remains one of the leading causes of morbidity as well as mortality globally, and despite of the incremental improvements from the point of surgery, radiotherapy, as well as systemic drugs, substantial unmet needs that mainly persist for the context of efficacy with reduced toxicity and improved patient quality of life. Whereas therapeutics, diagnostics, and theragnostic methods offer alternatives in the local delivery and toxicity of medications in drug induced anoxia, nanomedicine by providing them with means to surmount these challenges; it can transform biodistributions of therapeutic substances in target delivery, control immune reaction, and integrate therapeutic and diagnostic purposes. Nano scaling encapsulation has demonstrated multiple examples of changes in the pharmacokinetics of drugs: first clinical proofs of nanoscale-specific encapsulation effects, as demonstrated with pegylated liposomal doxorubicin and other formulations based on nanocarriers, have shown that pharmacokinetic effects of the drug could be influenced by nanoscale encapsulation to reduce dose-limiting toxicity and even increase efficacy (Jadhav *et al*., 2024). In the context of the COVID-19 pandemic, the clinical introduction of lipid nanoparticles (LNPs) to deliver mRNA vaccines added new momentum to the field and demonstrated that the nucleic acid-based therapeutic nanoparticle platform was open to both large-scale and high-throughput applications that were estimated to deliver a dose of nucleic acids.

In this timely brief critical summary, this essay briefly summarises the clinical state of nanomedicine in cancer therapy pinpointed at known clinical applications and the future plan involving translational prospects. It also surveys those nanocarriers with clinical or late-stage translational relevance, is a summary of clinical outcome where present, enumerates translational challenges, and suggests practical future interventions in aligning design, manufacturing and regulatory practice with clinical need (Zhang *et al*., 2023). Weaknesses in the approaches of the current body of literature like publication biases and disparity in reporting of clinic outcome are examined and a guidance to improve the evidence base provided.

## BACKGROUND AND RATIONALE

There are many physics chemical properties that make nanoparticles attractive to apply in oncology (Thapa *et al*., 2023). They can exploit tumour tumour versus normal physiology disparities at lengths, commonly between 10 and 200 nanometres to passively accumulate (such as through the enhanced permeability and retention effect), be functionally altered to do active targeting to a receptor upon tumour cells or on tumour microenvironment receptors and to be programmed to release their Salvoes in response to local signals (e.g. pH, enzymes or temperature) (Rehan *et al*., 2024). Poorly soluble drugs can be encapsulated in nano systems, labile biologic

molecules such as nucleic acids can be encapsulated, and the deployment of multiple agents to realize synergistic effects in therapeutics can be incorporated into the nano system. However, the most important design limitation that should be considered during translation between the bench and bedside are biological barriers (serum proteins and opsonization, mononuclear phagocyte system, heterogeneous tumour vasculature, dense extracellular matrix).

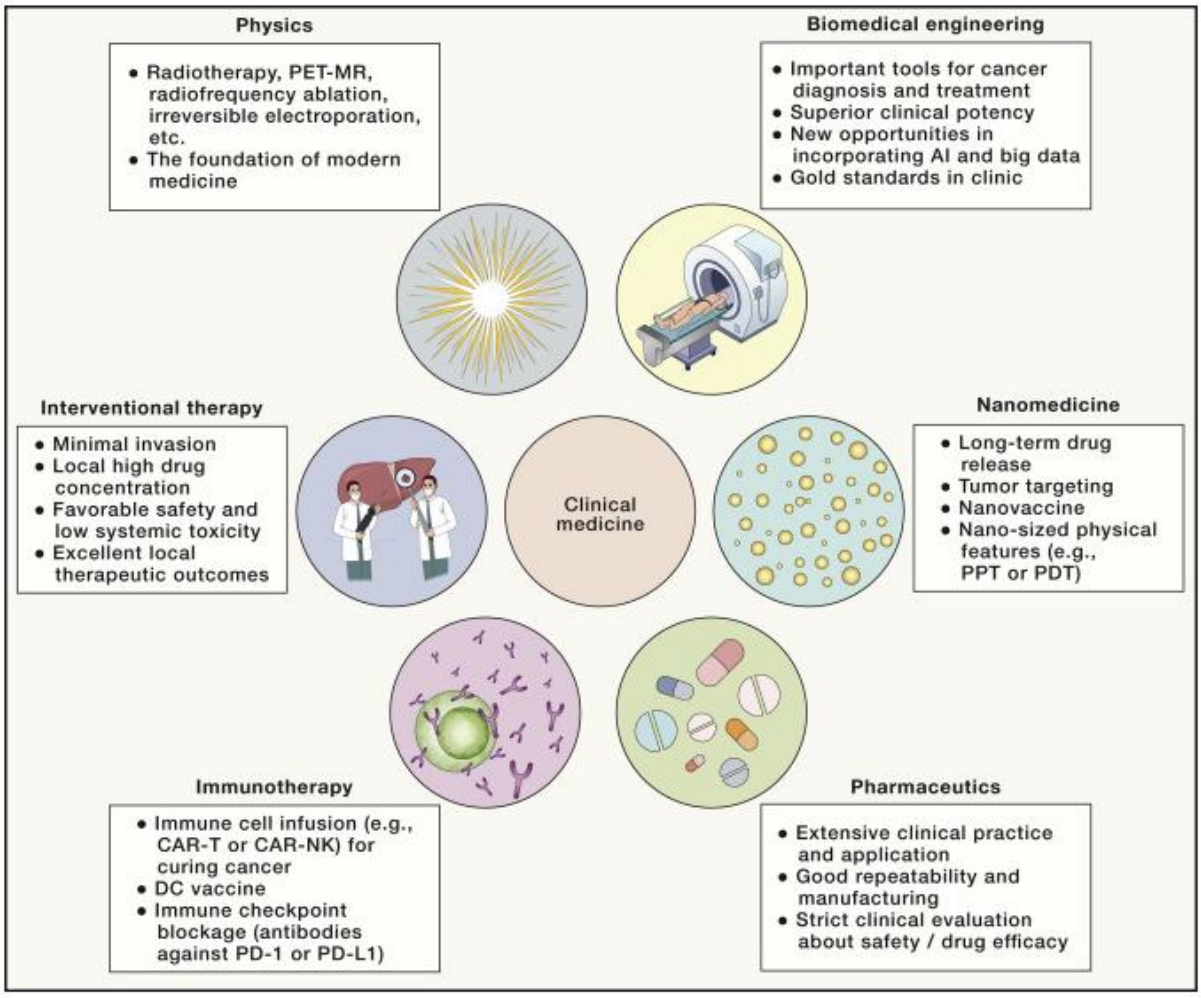


**Figure: Cancer nanomedicine toward clinical translation**
(Source: Zhang *et al.*, 2023)

The reasoning of nanomedicines in oncology can then be formulated in two manners (Xu *et al.*, 2023). These could improve the therapeutic index of existing cytotoxic and molecular therapies, either by reducing off-target effects and permitting higher or higher levels in the intratumor environment. Second, they can enable delivery that would be clinically challenging such as siRNA, mRNA, and gene-editing agents through facilitating delivery to the appropriate tissue and cell population and through lowering systemic degradation and immunogenicity. The preclinical outcome of LNP-mRNA vaccines of infectious disease have established a blueprint in applying RNA nanotechnologies to cancer, such as customized neoantigen vaccines, mRNA coded biologics to reprogram antitumor immunity.

## LITERATURE REVIEW

### 3.1 Clinically Approved Nanomedicines and Lessons from Their Use

The initial round of nano medicinal oncology clinical approvals was liposomal and albumin-bound analogy of small molecule chemotherapeutics to alleviate the toxicity levels of the original drugs (Anchordoquy *et al.*, 2024). Recipes of pegylated liposomal doxorubicin (PLD) also exhibited better safety profiles in various indications, longer circulation periods, reduced cardiotoxicity and distribution zones than free doxorubicin. Albumin-conjugated paclitaxel utilizes the natural pathways of albumin transportation to facilitate the tumour cell absorption of paclitaxel and reduce solvent toxicity that is found in solvent-dependent preparations. Such clinical results demonstrated that alterations in the pharmacokinetics and biodistribution have the ability to induce a clinically meaningful effect even in situations when the active pharmacophore itself remains constant (Omidian

*et al.*, 2023). However, increased safety does not always lead to a substantial alteration in efficacy and many nanoparticle preparations have not gone through randomized trials which can demonstrate increased survival with improved pharmacology. The systematic reviews of the clinical failures show that the clinical failures were associated with poor intratumor delivery, poor patient selection, and overuse of poorly developed preclinical models, which need to be used to predict human tumours.

### 3.2 Lipid Nanoparticles and Nucleic Acid Therapeutics

The amplified attention to lipid nanoparticles secured more news headlines in the publication than any previous event since the swift manufacturing and utilization of mRNA vaccines against SARS- CoV-2 (Omidian *et al.*, 2023). Flat LNP investigated the clinical practicability of the systemic administration of nucleic-acid and endorsed in-service lessons as well as formulation, immune activation, and large-scale production. Similar lipid-based systems (LNPs) are used in oncology to encode tumour antigens as an individualized vaccine, mRNA based cell therapies, siRNA silencing oncogenic drivers and mRNA combinations to regulate the tumour microenvironment. Within cancer trials in both clinical trials and compassionate-use studies, LNP-based cancer vaccines have demonstrated the potential to elicit antigen-specific T cell responses, as well as rare objective clinical responses, combinations with immune checkpoint blockade. Nonetheless, effective intracellular delivery to the relevant antigen-presenting cells and long-term functional responses still are not investigated.

### 3.3 Polymeric and Inorganic Nanocarriers

The nanoparticles may be in form of polymeric nanoparticles, dendrimers, and inorganic nanoparticles such as gold and iron oxide nanoparticles to offer special advantages to controlled release, imaging contrast enhancement, and combination theragnostic. Various of these platforms have already clinical trial results indicated with clinical trials representing such diseases as glioblastoma, in which there are limitations on blood-brain barrier (BBB) by other traditional treatment systems (Zhang *et al.*, 2023). Second generation capture methods of getting BBB-targeted including ligand-mediated transcytosis and temporal BBB-modulation have proven to be preclinically efficacious, translational efficacious, and have not been clinically effective in demonstrating improvement in survival of brain tumours. The delivery limitations of systemics have also not been held in as much regard as the use of metallic nanoparticles as radiosensitizers and photothermal agents, as a treatment can be considered localizable.

### 3.4 Clinical Trial Landscape: What Human Studies Tell Us

A recent systematic review of the published human clinical trials in nano-particles therapeutics paints a malevolent but educative picture: safety profiles tend to be agreeable; pharmacokinetic advantages are provable; however objective clinical benefit hypotheses conventional therapies are rarely reported and tend to be minimal in randomized studies (Wang *et al.*, 2024). The most frequent combination approaches with positive messages are the co-delivery of nanoparticles to immunotherapies or the regulation of the tumour microenvironment and these have generated motivation that the way forward to essential progressions in efficacy can be simplified. Relevant heterogeneity in endpoints, biomarker-directed selection of patients, and inconsistency in the characterization of nanoparticles are also rather noteworthy heterogeneity in the landscape of trials, and it is hard to cross-trial to compare and synthesize meta-analyses.

## METHODOLOGY

### 4.1 Review Design and Conceptual Framework

The existing study is an evidencing literature review in the shape of a story that is bound to examine in a critical manner the clinical translation of nanomedicine in oncology. The specific application of a narrative methodology rather than a formal systematic analysis or meta-analysis was because the nanomedicine field is a very heterogeneous one in terms of nanoparticle platforms, therapeutic payloads, cancer indications, and clinical endpoints. This variety limits the capacity to conduct statistical summarization and maximizes the value of an integrative, explanatory synthesis (Vikal *et al.*, 2025). The translation relevance methodology focus is addressed based on the importance that is accorded to human clinical relevance and late preclinical studies having direct clinical application, regulatory implication and research future directions.

The conceptual orientation of the review is clinical rather than a technology-based oriented one. The methodology has to do more with how nanomedicine platforms behave in the real-life geneses of the clinical environment, which include safety, efficacy, pharmacokinetics, immunological effects and scalability of nanomedicine technology. Through this plan, similar challenges and success factors of nanotechnology in the common modalities can be determined.

### 4.2 Literature Search Strategy

The effective publications were identified by the powerful literature search according to the information published no later than January 2015 and not later than December 2025 to discover the modernization of nanomedicine, among which there are the introduction of nanoparticles based on lipid nanoparticles and RNA technologies (Nhàn *et al.*, 2023). A number of electronic databases and knowledge sources were consulted, in

such a way that biomedical, translational and regulatory literature were greatly represented. The sources included PubMed Central, big scholarly publishers as well as open access clinical trial registers.

The search queries were constructed on the basis of the controlled vocabulary terms and the free-text keys which are related to nanomedicine and oncology. The keywords employed in core #1 were nanoparticle, nanomedicine, liposome, lipid nanoparticle, polymeric nanoparticle, mRNA, siRNA, drug delivery, clinical trial, cancer, and oncology (Andreani *et al.*, 2024). Refinement and search were done using the aid of Boolean operators to reduce results that were not relevant. Other relevant studies that cannot be located in database searches were also weeded using key review article reference lists.

**4.3 Inclusion and Exclusion Criteria**

The inclusion criteria were set with an aim of revealing the clinical and translational relevance of literature under investigation. The priority given was given to peer-reviewed systematic reviews, narrative reviews in high impact journals, phase II and phase III clinical trial reports, late-stage translational data and human data studies, regulative or policy reports on nanomedicine approval and use of nanomedicine. It was included when the initial clinical trials carried out strong pharmacokinetic, safety or mechanistic evidence that directly is connected with the further development.

These initial preclinical studies were not excluded but were picked and chose specifically on the basis of dealing with clinically relevant mechanisms e.g. tumour penetration, immune modulation, biodistribution, blood-brain barrier translocation or resistance mechanisms in human studies (Mohammadi *et al.*, 2023). The investigations that did not incorporate any actual translational relationship between the research and inferred only in vitro research or an animal model were stopped. In order to make the methodology rigorous, other language publications, abstracts of conferences where all the data was not contained and opinion articles which were not substantiated with empirically obtained data were also removed.

**4.4 Data Extraction and Synthesis**

The procedure of data extraction used was the qualitative one; it focused on the thematic and not the numerical aggregation (Zhang *et al.*, 2025). The background on the purpose of selecting key data of each selected source comprised type of nanoparticle, therapeutic payload, cancer indication, clinical phase, primary and secondary endpoints, safety and toxicity, pharmacokinetics and the described clinical results. Immunological effects, i.e., T-cell activation, cytokine effects, and biomarker correlation relation were also considered in the example of immunotherapy-based nanomedicine.

This synthesis process comprised the aggregation of the studies on the thematic areas including clinically approved nanomedicines, lipid nanoparticle based nucleic acid therapeutics, polymeric and inorganic nanocarriers, and novel applications including tailored cancer vaccines as well as brain tumour delivery (Zhao *et al.*, 2023). The patterns between the studies were chosen to compare the differences and similarities between the clinical performance, translational barriers, and regulatory results. In place of statistical weighting of studies, the better designed clinical trials, extensive reviews and studies with clear methodology and reproducible outcomes were assigned more weight in an interpretive manner.

**4.5 Emphasis on Clinical and Regulatory Relevance**

The point that can be identified in the approach is its emphasis on the applicability of clinical use and regulatory translatability (Kubiatowicz *et al.*, 2022). The regulatory guidance documentation, post-marketing surveillance documents and the outcome analysis of the clinical trials were pooled together in order to position the efficacy and safety results within the real-life approval and adoption trajectories. This allowed both the review to not only establish whether nanomedicine approaches are operating or not, but also whether they can be manufactured, saleable and can be approved under the current regulatory systems.

Comparative study of nanoparticle-based therapy against conventional formulations was highlighted in case it was possible to determine incremental clinical benefit (Xu *et al.*, 2025). Other features of interest included the design of trial including patient selection, combining biomarkers and endpoint choice because these variables are of critical importance in the translation success.

**4.6 Methodological Limitations**

Several limitations that the employed methodology possessed are identified. As a narrative review, the study has a high risk of a selection bias, which is particularly the positive or high-profile studies (Ling *et al.*, 2023). The impossibility of covering the statistically broad conclusions between the heterogeneous trials, in its turn, is limited by the absence of formal quantitative synthesis. It also did not succeed in cases and unpublished information that could have captured the new trends but the field was growing at a high rate and could underrepresent this.

Nanoparticle characterization, clinical outcome, and reporting standards differ among various research and thus pose an even greater challenge in directly comparing them due to variety. To cover such inadequacies, the review actively refers to the original clinical trial reports and primarily published reviews and allows the reader to

evaluate the primary data sources independently (Ibrahim *et al.*, 2025). However, the limitation notwithstanding, it is evident that the methodology offers a sound and clinical important synthesis of the available evidence and the results can be applied directly to individuals with interests in the research topic, practitioners, and policymakers with interest of advancing nanomedicine in oncology.

## RESULTS AND ANALYSIS

### 5.1 Pharmacokinetics, Safety, and Tolerability in Humans

The clinical benefits that have been achieved the most often following measures related to nanomedicines refer to the changed pharmacokinetics and an increase in tolerability. It is the case that pegylated liposomal-formulations reduce peak plasma concentrations of encapsulated cytotoxic, reduce the exposure of vital organs and thereby, reduce toxicities in addition to dosing that is the classic example of anthracyclines being cardiotoxicity. Preparation of albumin-bound preparations excluded the usage of toxic solvents and led to alternative outlines of the adverse events taking place during infusions (Dudhat *et al.*, 2025). A previously described pattern of predictable reactogenicity has been observed in trials of LNP-based nucleic-acid delivery had been observed in oncology and safe use with the prospect of manageable safety profiles given the correct dosage and formulation has been demonstrated. Combined with those of human beings, these data confirm the assumption that nanocarriers can mitigate some of the toxicity pathways and suggest a less hazardous therapeutic index with drugs of low margins.

### 5.2 Efficacy Signals and Clinical Endpoints

Nanomedicine vs standard formulations randomized trail involves the use of agents in nanomedicine which has shown mixed efficacy outcomes (Sengar *et al.*, 2024). Parallel efficacy and reduced toxicity have been observed in other settings; in still other similar observations, an improvement in the progression-free survival or response rate has been seen modestly to improve the overall survival diminutively without consistent gains. One might mention that a mix of paradigm, i.e. the interaction of nanomedicines with immune checkpoint inhibitors or targeted agents have also provoked some of the more encouraging clinical signals, presumably due to the restoration of tumour milieu to greater immunogenicity or the achievement of more desirable local concentrations of cytotoxic agents. The concept efficacy is also complicated because of trial variation in the design, endpoint selection and in patients and this makes both biomarker-oriented trial design and outcome measure criteria standards essential to the industry.

### 5.3 Translational Bottlenecks Identified from Clinical Experience

It has a series of overlapping translational bottlenecks that keep reemerging on the clinical literature. The inherent differences between tumour types and intercessions in the same patient in terms of natural differences in the microenvironment of tumours are, first, a drawback in passive targeting techniques and reduces predictable intratumor uptake. Second, the systemic clearance of the mononuclear phagocyte system and formation of the protein corona alters the identity of nanoparticles in vivo that is not easy to recapitulate in vitro characterization in human pharmacology (De Sousa *et al.*, 2023). Third, production of more multifunctional and complex nanoparticles have been identified to be challenging and expensive in scale-up and lot-to-lot consistency and affects reproducibility and regulatory approval channels. Finally, the rules regulating the field are currently still in the transition to handling hybrid products that blur the lines between drugs, biologics, and devices and this ambiguity can potentially be used to delay translation.

### 5.4 Emerging Clinical Areas: RNA Vaccines, Cell Therapy Support, and Brain Tumours

LNPs have rapidly advanced into the preclinical phase of clinical trials to invoke the evidence-based use of LNPs to deliver mRNA to generate personalized vaccines against the tumour, with evidence of both distinguishable immunogenicity and prior tumour response upon co-use with checkpoint inhibitors (Parvin *et al.*, 2024). The LNPs are also under consideration to deliver mRNA ex vivo/in vivo to program T cells or natural killer cells that can make production processes of cellular therapies easier. Nanoparticles techniques are applied in the treatment of central nervous system tumours such as glioblastoma to improve transport into the brain parenchyma by either receptor-mediated transport across the blood-brain barrier or by local intracranial delivery. The outcome of the initial trials conducted to humans in these areas is encouraging on mechanistic and immunogenicity scales yet high efficacy data is yet to come.

## DISCUSSION

### 6.1 Reconciling Preclinical Promise with Clinical Reality

The literature has one common characteristic feature the disconnect between robust preclinical efficacy and reduced clinical outcome (Domingues *et al.*, 2022). Several reasons have been credited to this gap. The immunodeficient xenografts of tumours in complex mice fail to reproduce complexity, stromal architecture, immune ecosystem and vascular heterogeneity with human tumour biology. Such discrepancies lead to overestimation of both intratumor nanoparticles and treatment. In addition, dose and infusion variables contextualization of small animals to human alteration of the pharmacokinetics and biodistribution which is not predictable at all times via preclinical studies (Wei *et al.*, 2023). The main ways through which researchers can

bridge this gap in translatability are by concentrating on predictive models based on animals, incorporating human-relevant in vitro models (such as organoids and micro physiological systems) and designing early-phase human trials that can measure intratumoral delivery and immune correlates as prime indicators of translatability.

### 6.2 Design Principles for Next-Generation Nanomedicines

Nanomedicines innovations Nanomedicines are likely to follow various set principles of convergent design in the future. These hierarchical forms of targeting where circulation stability, extra-vasoactive tumour cell movements, stromal penetration and cell uptake will be targeted sequentially will be ideally better than a single passive event delivery. Sensors which respond to the liberation of stimuli in the tumour microenvironment can also enhance therapeutic index (Jiang *et al.*, 2023). Diagnostic-therapeutic Capabilities (theragnostic) Multifunction carriers with integration of imaging, targeting and liquidation release these functional elements offer real-time patient selection and dosing. It is noteworthy that the protein corona and the MPS interactions must be directly put into the engineering of engineering strategies which must come up with stealth and the so-called bio-mimetic properties that can change the immune recognition without interfering with the target interaction.

### 6.3 Integration with Immuno-Oncology

The two components that can be used to achieve improved clinical outcomes are nanomedicine and immuno-oncology. Nanoarrays can either be applied to immunostimulatory carrier, adjuvants or mRNA vaccines to antigen presenting cells to provoke the robust T cell effect, or repressive tumour microenvironment components, such as regulatory T cells or myeloid-derived suppressor cells (Huang *et al.*, 2022). Combination immunologic responses and early evidence of efficacy have been seen in preclinical trials of nanoparticle vaccine combinations with PD-1/PD-L1 inhibitors, but the larger and biomarker-informed trials are needed. Nanoparticles are also able to increase the safety and efficacy of cytokine therapies and bispecific constructs depending on localization of activity to tumour or lymphoid tissues.

### 6.4 Manufacturing, Quality Control, and Regulatory Considerations

The physical and chemical aspects of nanoparticles are complicated necessitating reproduced manufacturing that is scaled and high control of quality. Quality attributes such as particle size distribution, surface charge and encapsulation efficiency, release profile and sterility cannot be tested in small scale and can only be tested on large scale. The regulatory agencies should demonstrate layered production and safety; however, the way of complex nanomedicines is still to be developed (Xu *et al.*, 2025). The interagency coordination, more specifications regarding characterization and nonclinical testing, and the fact that the regulation is engaged early on are required to accelerate the approval and guarantee the safety of the patients. Public-privacy alliances, and consortia, may make a great input in the development of standardization and the sharing of best practices.

### 6.5 Patient Selection, Biomarkers, and Trial Design

The successful translation will be grounded on patient selection depending on the advice of biomarkers and adaptive trials design that will enable the prompt evidence of whether the delivery is effective and the immunologic responses to support escalation and combinations. Imaging surrogates of accumulation and circulating tumour DNA as disease burden and immune predictors of vaccine response are biomarkers that can be used to predicting accumulation, circulating tumour DNA, and nanoparticles as antigens (Prajapati *et al.*, 2024). Such powerful pharmacodynamic endpoints as tissue-based endpoints whenever feasible should be employed in phase I/II trials to confirm a mechanism-of-action and provide a guideline to proceed with other randomized trials. Such an evidence-based approach will reduce failure in the late and increase the chances of clinical benefit in relation to nanoparticles being turned to clinical benefit.

## FUTURE DIRECTIONS AND STRATEGIC RECOMMENDATIONS

### 7.1 Prioritize Mechanistic, Biomarker-Rich Early Trials

The phase 1 trials should be developed to give the mechanistic responses on the delivery, intratumoral pharmacokinetics and interaction of immune responses (Jiang *et al.*, 2024). Concomitance of co-primary objectives of incorporation of paired biopsies, employer imaging and characterization of the nanoparticle as a standard performs directly whether a candidate formulation has achieved its desirable target and instigates the relevant biological response.

### 7.2 Develop Tumour-Penetrating and Stimuli-Responsive Platforms

The design should be further pushed to deeper stromal penetration-engineered carriers and must be stimulated in response to tumour-specific signals (Parvin *et al.*, 2024). Multi-stage systems that release smaller more penetrative particles or molecules when they enter the tumour would perhaps circumvent diffusion limitations that bedevil most other nano systems.

**7.3 Leverage RNA Nanotechnologies for Personalized Oncology**

The personalized neoantigen vaccines, intratumoral mRNA-coded cytokine therapies and mRNA in vivo cell engineering have an available foundation based on the achievements of LNP-mRNA platforms of vaccines during the pandemic (Domingues *et al.*, 2022). It will be necessary to translate the immunogenicity to the attainment of durable clinical benefit through computational pipelines of neoantigens, dosing models optimization, and the neoantigen combination immunotherapy trials.

**7.4 Address Manufacturing and Regulatory Gaps**

Lowering in cost and friction in regulation Investment in tech so as to ensure consistency of the batches, scale parcelled encapsulation strategies, and real-time testing of releases will be undertaken (Wei *et al.*, 2023). The developers and regulators should liaise on harmonizing the guidance regarding complex nanotherapeutics like the use of standard methods of characterization, nonclinical testing of safety and clinical endpoint on multifunctional products.

**7.5 Embrace Multidisciplinary, Patient-Cantered Development**

Data Clinical oncology Clinical oncology is regarded as requiring the integration of material science, systems biology, clinical oncology, regulatory science and patient-centred outcomes to succeed (Huang *et al.*, 2022). Preferably, developers should have prior consultations with clinicians and patient advocates to adequately match product properties with clinical interests- balancing non-significant effects on safety with those of significant effect on survival or quality of life.

## CONCLUSION

Nanomedicine has already demonstrated itself to increase safety and in certain instances efficacy of oncology therapeutics. The local delivery and endogenous ideas of the changed pharmacokinetics have been clinically confirmed employing fundamental principles and surfacing of LNP-delivered RNA therapeutics has developed the technological repertoire into a scope of customized vaccines and in vivo cellular treatment. Nonetheless, the gaps in translation to general, consistent clinical benefit have been constrained by gaps in the biological complexity, manufacturing and in trial design and use of biomarkers. The solutions are severe mechanistic initial-stage trials, smarter planning of the carriers, which escape biological hindrances, strategic partnership with immunotherapies, and joint efforts to align the ambition of manufacturing and regulative necessities. With these priorities in place nanomedicine has the possibility of fulfilling their engineering concept of a disruptive pillar of precision oncology, and the adequate means of offering safer and more effective solutions to the needy.

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