From Trial-and-Error to AI-Guided Nanomedicine: Accelerating the Discovery of Next-Generation Therapeutic Nanoplatforms

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Cardiovascular diseases remain the leading cause of mortality worldwide, with myocardial infarction (MI) being a major driver of heart failure due to the irreversible loss of cardiomyocytes,[1] excessive fibrosis, chronic inflammation, and adverse ventricular remodelling. Despite major advances in interventional cardiology and pharmacotherapy, current treatments largely slow disease progression rather than regenerate damaged myocardium. The development of effective regenerative therapies therefore represents one of the greatest challenges in contemporary medicine. Recent advances in nanomedicine have generated unprecedented opportunities to precisely modulate biological pathways involved in cardiac injury and repair through targeted delivery of drugs, nucleic acids, proteins, and bioactive molecules.[2-6]

Over the past decade, our group has pioneered multiple nanomedicine-based strategies for cardiovascular regeneration, including cardiac-targeted nanoparticles, fibroblast reprogramming systems,[2] RNA-delivery platforms, mitochondria-directed therapeutics, biomimetic nanocarriers, and advanced biomaterials for myocardial tissue engineering.[4,6,7] Early studies demonstrated multifunctional nanoparticles capable of selectively targeting the injured myocardium and modulating pathological hypertrophic signalling. Subsequent work introduced dextran-functionalized nanoparticles designed to reprogram cardiac fibroblasts and reduce fibrosis, addressing one of the major barriers to functional cardiac recovery after MI.[1,3,5] These developments have paved the way towards increasingly sophisticated therapeutic systems capable of simultaneously promoting regeneration, reducing scarring, and restoring cardiac function.[4]

More recently, our research has expanded beyond conventional nanoparticle design toward the integration of artificial intelligence, advanced biomaterials, and regenerative bioengineering. AI-enabled approaches now offer the possibility of predicting nanoparticle composition, biological performance, cellular interactions, and therapeutic outcomes before experimental validation.[1,2,5] By combining machine learning, computational modelling, automated formulation screening, and multimodal biomedical datasets, nanomedicine development can shift from empirical trial-and-error approaches toward predictive and data-driven design.[3] This paradigm is particularly attractive for cardiovascular medicine, where the biological complexity of post-infarction remodelling demands multifunctional therapeutic interventions.

Overall, this presentation will highlight how AI-guided discovery is accelerating the design of next-generation therapeutic nanoplatforms and discuss future opportunities for translating cardiovascular nanomedicines from laboratory innovation to clinical impact.[2,6,7]

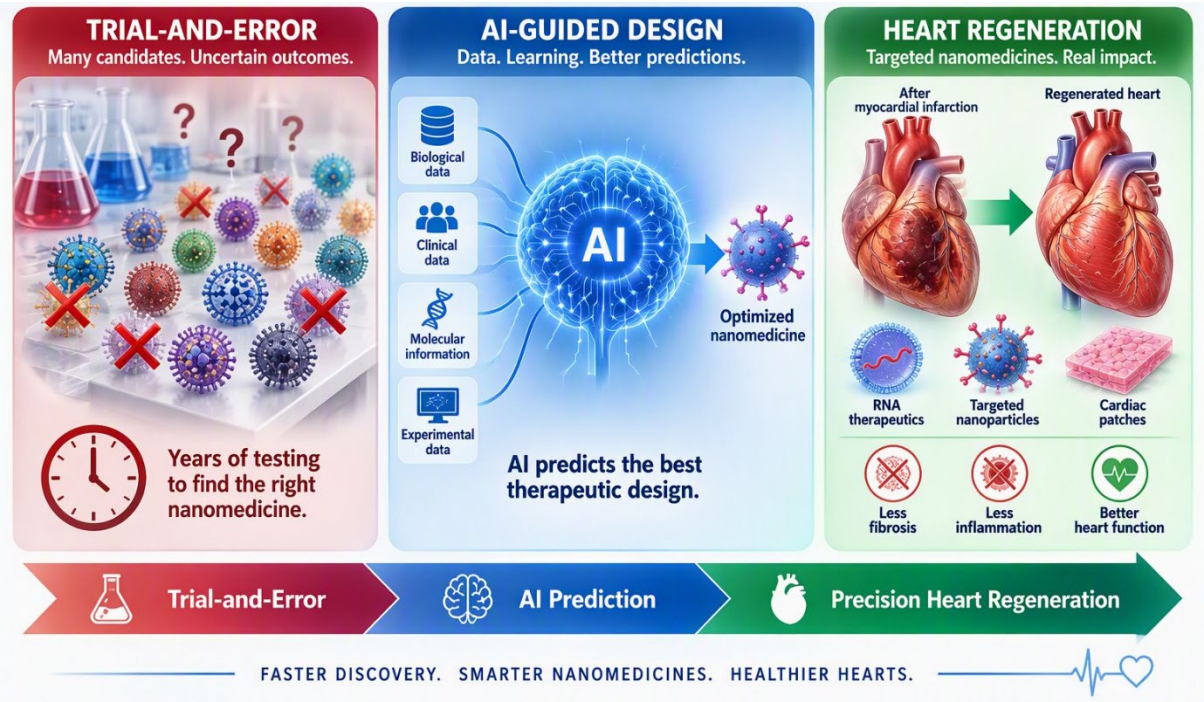


***Figure 1*:** From trial-and-error to AI-guided nanomedicine: accelerating discovery for hear repair.

References:

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