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Carbon Nanotubes in Pharmaceutics: Structure, Functionalization, and the Path to Clinical Translation

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Abstract: *CNTs, including single-walled (SWCNTs) and multiwalled (MWCNTs), are a highly versatile class of nanomaterial because of their unique structural, mechanical, and physicochemical properties as well as for their wide range of feasible applications in pharmaceutical sciences. Their high aspect ratio, hollow tubular structure and π-conjugated surface can facilitate drugs loading and release processes as well as interactions with therapeutic molecules, in which the functionalization via covalent, non-covalent or hybrid modes could improve solubility, biocompatibility and targeting ability. CNTs have been widely studied as drug and gene/RNA delivery, imaging, theranostics (therapeutics-diagnostic) formulation and tissue- engineering material –illustrating enhancement in cellular uptake, decrease systemic toxicity, multi- functional therapeutic potentialities. several tremendous advancements, issues with kinetics, biodistribution, chronic toxicity, immunity and approval standardization continue to restrict translation into clinical trials. Precision pharmaceuticals may be made possible by new developments like bioelectronic scaffolds, stimulation-responsive systems, artificial intelligence-driven design, and hybrid CNT-based nanotechnology. The article outlines an approach for the safe and efficient integration of CNTs into next-generation medicinal product and healthcare devices by providing a thorough analysis of their structural features, functionalization techniques, medical uses, medicinal considerations, and translational challenges.*

Keywords*: SWCNTs*

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