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The use of Carbon Nanotubes in Medical Applications - Is It a Success Story?

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Since their rediscovery [1] by Iijima [2] carbon nanotubes (CNTs) have attracted a lot of interesting research due to their outstanding properties that have potential impact on broad areas of science and technology [3]. The name CNT originates from their nanometer-scale size. An ideal nanotube can be described as a network of carbon atoms assembled into a cylinder, which is covered at the end by half a fullerene molecule [4,5].

It's the small dimensions that make CNTs to hold a lot of potential for medical applications [6]. For instance, the potential of CNTs to carry drugs in the organism lies on the fact that they are hollow and much smaller than the blood cells [7]. Furthermore, CNTs can be easily modified with a wide variety of molecules through several procedures [6]. For example, proteins and other molecules can be incorporated onto CNT structures [8]. The practical uses of CNTs in biomedical and biotechnology include their use as channels for biosensors, delivery of drugs, and sheathe for enzymes and transfection of DNA. Actually, CNTs are poised to be the next generation of drug delivery systems for several reasons which include: water dissolvability, highly stable dispersion, absence or limited intrinsic immunogenicity and an effective loading capability [9]. For example, on the basis of their polymeric and cationic nature, soluble functionalized CNTs are able to go through a cell without changing its form and structure [9-11]. In fact, one of the main desirable features of the CNT is its ability to transport drugs right away to targeted cells and tissues [12]. Targeting drug delivery system improves the therapeutic efficacy and reduces the systemic toxicity. Applications of CNTs are also giving rise to the manufacturing of materials and pieces of equipment such as scaffolds for cell and tissue engineering, and sensors that can be used for observing and checking the progress of some aspects of human health [8]. In addition, CNT's have capacity to capture the pathogenic bacteria as CNTs themselves possess anti-microbial properties.

However, there are a number of challenges that need to be resolved before the potential of CNTs is fully realized for medicinal purposes [7]. One of the main drawbacks of CNTs is their hydrophobicity. Therefore, several researchers have developed a number of solubilization and dispersion methodologies. For example, in order to exploit their biomedical applications [13], CNTs have been chemically functionalized [14] or covered with amphiphilic molecules such as PEGylated phospholipids or polymers [15]. Secondly, their integration with biological systems needs a thorough assessment of safety, as well as comprehension of their marked effect on the surroundings [9,16]. In fact strong emphasis is given to the evaluation of their toxicity and biocompatibility before integrating them into biological substrates [9]. At present, only a limited number of studies with many open questions have been published. Currently, verification studies have shown that CNT can act as distribution systems for drugs, antigens, and genes into cells with slightest cell poisoning [13]. However, their exposure and uptake in biological systems and potential toxicity remain uncertain. The in-vitro and in vivo studies conducted so far are inconclusive because of the varied evidence established to cell lines. Nevertheless, CNTs particularly multi-walled CNT have shown that upon inhalation by exposed workers, the elemental carbon mass concentration was estimated at an arithmetic mean of 10.6 $\mu g/m^3$ (geometric mean 4.21 $\mu g/m^3$) [17]. In all these studies, the difficulty that remains is due to the vast diverse surface and physiological properties of the CNTs, sizes, the various attached ligands, the bioaccumulation of the nanoparticles after cell delivery and the hypersensitivity reactions that may emerge during the course of action. However, the risks for health are possibly linked to the existence of metal components or catalyst used during their production [9]. Actually, free iron and nickel, as well as transition metal complexes, have been recognized as catalysts for free radical reactions that are precarious in living systems [9,18]. We, therefore, encourage further proper toxicological studies of CNTs and other nanoparticles to be determined before their bio-applications in diverse bio-systems.

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