Biological Applications of Carbon-based Nanomaterials: From Functionalisation to Biodegradation

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Carbon based-nanomaterials (CNMs), including carbon nanotubes (CNTs) and graphene, are promising tools owing to their outstanding properties and large surface area, offering a variety of opportunities for applications in nanomedicine, such as diagnosis, disease treatment, imaging, and tissue engineering.[1,2] But, the low solubility of CNTs and graphene-family nanomaterials in most organic solvents and in water hampers their manipulation and limits the full exploitation of their properties. Hence, surface functionalization is crucial to increase the biocompatibility of CNMs and impart multiple functionalities. The oxidized form of graphene, graphene oxide (GO), is often used as starting material for the preparation of graphene derivatives for biomedical applications as the presence of polar oxygen-containing species makes it more hydrophilic than pristine graphene. This is fundamental for further functionalization and processability. Health impact and biopersistence, along with environmental accumulation are key issues for the development of CNMs in the biomedical field and other related areas. It is essential to evaluate their systematic toxicological effects before their use in different domains.

In this talk, I will show whole body imaging and pharmacokinetic data following intravenous administration of functionalized GO in mice.[3] Biodistribution studies have important implications in the design of graphene-based nanomaterials for therapy, imaging, and diagnosis, as well as for the determination of their safety profile. Understanding human health risk associated with the rapidly emerging graphene-family nanomaterials represents a great challenge because of the diversity of applications and the wide range of possible ways of exposure to this type of materials.

It is mandatory to elucidate the key aspects associated with biodegradability of CNMs for their real translation into possible clinical innovations as well as for their safe disposal in the environment. In this context, I will report our study on the biodegradation of GO by myeloperoxidase derived from human neutrophils.[4] The degradation capability of the enzyme on three different GO samples displaying a variable dispersibility in aqueous media has been compared, revealing that MPO failed in degrading the most aggregated GO, but succeeded to completely metabolize highly dispersed GO samples.

I will also present our work on the covalent functionalization of CNTs with specific functional molecules such as potential reducing substrates (coumarin derivatives) and redox mediators (catechol) to enhance the catalytic activity of horseradish peroxidase (HRP), leading to accelerated degradation of the nanotubes by the enzyme, in comparison to simply oxidized CNTs.[5] The results demonstrate the crucial importance of the type of surface functionalities onto CNTs as a strategy to modulate their enzymatic biodegradability. Our finding will certainly help to guide development of future biomedical applications using CNTs and GO by designing biodegradable carriers for drug delivery.

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