Carbon Nanotubes Continue To Show Promise in Battle Against Cancer

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Carbon nanotubes, one of the original engineered nanomaterials, also may prove to be among the most versatile, as numerous teams of investigators continue to develop novel nanotube-based therapeutic and diagnostic tools. Over the past month, three new research papers have highlighted the potential of nanotubes as weapons against cancer.

Reporting its work in the journal *Biomacromolecules*, a group headed by James R. Baker, Jr., M.D., University of Michigan, describes its success in linking single-molecule nanoparticles known as dendrimers to the surface of multiwalled carbon nanotubes. The resulting combination nanomaterial is highly stable, readily disperses in water, and is biocompatible.

The dendrimers that Dr. Baker's group uses function as targeting agents that deliver the nanotubes specifically to tumor cells that overexpress high-affinity folic acid receptors. Although other research teams also have developed methods for targeting nanotubes to tumors, this approach holds particular promise because dendrimers also can be modified to carry drugs and imaging agents as well as targeting agents. As a result, explained Dr. Baker, who heads one of the 12 National Cancer Institute Cancer Nanotechnology Platform Partnerships, this current research provides a one-step method for adding multiple functions to carbon nanotubes without the need for developing complex new methods for modifying the nanotubes.

Efforts to develop carbon nanotubes for use in cancer applications also received a boost from work presented in a set of two papers published in the *Journal of Biomedical Optics*. In these papers, a team of investigators led by Alex Biris, Ph.D., and Vladimir P. Zharov, Ph.D., D.Sc., University of Arkansas at Little Rock, describes methods for detecting, tracking, and killing cancer cells in real time with carbon nanotubes.

In their first paper, the investigators demonstrate that they can use a technique known as Raman spectroscopy to track carbon nanotubes as they move through a living animal. “Until now, nobody has been able to fully understand and study in vivo and in real time how these nanoparticles travel through a living system,” said Dr. Biris. “By using Raman spectroscopy, we showed that it is possible not only to monitor and detect nanomaterials moving through the circulation, but also to detect single cancer cells tagged with carbon nanotubes. In this way, we can measure their clearance rate and their biodistribution kinetics through the lymph and blood systems.”

Dr. Zharov emphasized that in vivo Raman flow cytometry is promising for the detection and identification of a broad spectrum of various nanoparticles with strong Raman scattering properties, such as cells, bacteria, and even viruses. “Before any clinical application of nanoparticles, it is imperative to determine their pharmacological profiles,” he said. “This tool will provide this function as a supplement or even as an alternative to the existing methods.”

In this project, Drs. Biris and Zharov and colleague Ekaterina I. Galanzha, M.D., injected a single human cancer cell containing carbon nanotube material in the tail vein of a test rat. They were able to follow the circulation of the carbon nanotubes in the blood vessels to the rat’s ear, tracking the cell through the rat’s bloodstream, lymphatic system, and tissue with a Raman spectrometer.

In their second paper, Drs. Biris and Zharov show that once carbon nanotubes reach tumors and their location is pinpointed using another technique known as time-resolved infrared thermal imaging, the nanotubes can be turned into miniature heaters through laser irradiation. The hot nanotubes then bake the tumors to death from the inside out. This set of experiments demonstrates that the cancer-killing process affects only the nanotube-labeled cancer cells, which disintegrate and die within a matter of hours after treatment. The investigators believe that this approach could be particularly useful for treating small tumors, tumor margins, and micrometastases.

Dr. Baker's work, which is detailed in the paper "Multifunctional dendrimer-modified multiwalled carbon nanotubes: synthesis, characterization, and in vitro cancer cell targeting and imaging," was supported by the NCI Alliance for Nanotechnology in Cancer, a comprehensive initiative designed to accelerate the application of nanotechnology to the prevention, diagnosis, and treatment of cancer. Investigators from Donghua University in Shanghai, China, and the University of Georgia also participated in this study. An abstract of this paper is available at the journal's Web site.

Drs. Biris and Zharov's work, which was supported with funding from the National Cancer Institute, is detailed in the papers "In vivo Raman flow cytometry for real-time detection of carbon nanotube kinetics in lymph, blood, and tissues" and "Nanophotothermolysis of multiple scattered cancer cells with carbon nanotubes guided by time-resolved infrared thermal imaging." Investigators from Louisiana State University also contributed to the second paper. Abstracts of these papers are available at the journal's Web site.
View abstract 1
View abstract 2

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