Journal of Nanotechnology in Engineering and Medicine

Editorial

Nano-Therapeutics and Nano-Imaging in Biotransport

Nanotechnology has been used extensively in the past decade in a variety of research fields including renewable energy, manufacturing systems, and biomedical engineering, to name a few. In biomedical engineering, the nanoscale sizes and large ratios of surface area to its volume of the developed nanostructures can confer remarkable physical or physiological properties to facilitate chemical, biological, and thermal interactions with cells and molecules in biological tissue. As a result, nanostructures have great potential as carriers of therapeutic agents, contrast agents in bio-imaging, and strong thermal energy generators or absorbers. Improved control over nanostructure size, shape, and surface coating allows rapid research advancements in diagnosis, imaging, and treatment for various diseases. However, there are also challenges when working at this size-scale. Targeted delivery of nanoparticles, controlled therapeutic agent release from nanoparticles into tissue, distributions of nanostructure-related thermal energy deposition for tissue damage, etc., are transport phenomena that are especially relevant for nanotherapeutics and contrast agents. These considerations require multiscale and/or multiphysical modeling and in vivo or in vitro experiments using living and biological systems.

This special section issue of the *Journal of Nanotechnology in Engineering and Medicine* focuses on the subject of biotransport in nanotechnology. The six papers included in this special section issue covers a diversity of nanoscale transport phenomena. Also highlighted is the tremendous progress which has occurred in the past decade using nanostructures in a newly defined role in hyperthermia treatment and drug delivery. In addition, theoretical simulations for designing treatment protocols and experimental studies for validating modeling predictions are important research contributions that are included in this special section issue.

Dr. Ayyaswamy et al. at the University of Pennsylvania provide a detailed review of the current status in theoretical modeling of drug delivery via nanocarriers. Although this review focuses on specific transport mechanisms involved in systemic drug delivery, many of the same modeling approaches apply to nanoparticle delivery via other routes. This paper highlights the tremendous progress in recent years due to the advancements in computational resources and computational methods. The authors are also keenly aware that the success of the transport simulations depends on experimental validation, especially calling for studies that isolate individual transport mechanisms for a data-driven modeling approaches and quantitation of underlying transport processes. Development of new therapeutic nanocarriers is also needed. The study by Ferrer et al. from the University of Pennsylvania examined the potential of versatile lysozyme-dextran nanogels as drug carriers. They verified uptake and release of these novel carriers in different cell lines in addition to demonstrating the stealth properties, which allow these carriers to evade uptake by differentiated macrophages.

Validation of theoretical simulations of nanostructure deposition in tissue requires imaging techniques that can detect nanostructures or biophysical signatures associated with nanostructures. Included is a study by Xu et al. at Purdue University that explores feasibility of using an elastic light scattering-based spectroscopic image technique to detect micro/nano scale alternations in extracellular matrix structures. Although this technique is not used to directly visualize nanoparticles in tissue, it holds great promise in analyzing correlations between nanostructure deposition and induced local tissue structural changes, therefore, providing indirect evidence of nanostructure distribution after delivery. In the paper by Jin et al., the authors propose utilizing nanoparticle-induced temperature elevations for improved detection of skin cancer. This is based on the assumption that nanoparticles are selectively delivered to tumor regions due to surface coatings with affinity ligands that are specific to tumor cells. Laser scanning of the skin surface would then result in significant temperature elevations detectable by infrared thermography.

Traditional hyperthermia approaches such as microwave, radio-frequency, ultrasound, etc., have the limitation of inevitable thermal energy deposition in superficial tissue regions before the waves reach targeted tumor tissues. Magnetic nanoparticles and gold nanoshells/nanorods have significant potential to confine thermal energy to tumors with minimal collateral damage to the surrounding healthy tissue. Practical numerical models may be used to study this thermal therapeutic ratio for local hyperthermia. Pearce et al. at the University of Texas at Austin and Darthmouth College have developed a new formulation which accounts for fundamental heating mechanisms associated with nanoparticle clusters, realistic geometries, and multiple length scales. The study by Attaluri et al. at Johns Hopkins University presents a new method to calibrate magnetothermal calorimetric systems for superparamagnetic iron oxide nanoparticle suspensions, allowing for more accurate characterization of nanoparticle heating. Theoretical simulations by Jin et al. characterize nanoparticle enhanced thermal energy absorption in tumor regions using an incident 810 nm near-infrared laser, and the theoretical prediction is consistent with results from phantom gel experiments. A major challenge that remains in nanostructure-enhanced hyperthermia for cancer treatment is still in how to achieve controllable and repeatable delivery to obtain desired localization of nanostructures in tumors, since only a minor fraction of injected drug through the vein gets to the targeted tumor.

The papers included in this special section issue gives an interesting snap shot of the current research field in biotransport using nanotechnology. We hope that this special section issue will stimulate future discussion and collaboration among physicists, engineers, material scientists, and clinicians in this interdisciplinary research field.

Liang Zhu
Department of Mechanical Engineering,
University of Maryland Baltimore County,
Baltimore, MD 21250

Malisa Sarntinoranont
Department of Mechanical
& Aerospace Engineering,
University of Florida,
Gainesville, FL 32611