12th March 2025

12:00

Sala de Conferencias
Edificio I+D

Modulation of the cellular activities through biodegradable nanotransducers

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Polydopamine nanoparticles (PDNPs) have emerged as promising organic and biodegradable nanotransducers capable of modulating cellular activities through near infrared (NIR) light responsiveness, presenting significant potential applications in human healthcare. Recent studies have demonstrated the multitasking roles of PDNPs, ranging from neuroprotection, cell stimulation, and cancer therapy.

PDNPs exhibit strong antioxidant properties, effectively counteracting reactive oxygen species (ROS) accumulation in neuron-like cells. This antioxidative capability not only prevents mitochondrial dysfunctions induced by oxidative stress, yet also promotes neurite outgrowth, thereby supporting neuronal health and function.

Beyond their neuroprotective effects, PDNPs serve as efficient photothermal conversion agents. Following NIR laser stimulation, these nanoparticles can elevate intracellular temperatures, a process precisely quantified using fluorescent temperature-sensitive dyes and supported by mathematical modeling. This photothermal effect has been exploited to foster specific cellular functions, in particular neuronal and muscular activation.

By pushing the photothermal effect beyond the physiological range, NIR + PDNP stimulation demonstrated to be an effective approach in cancer therapy, by inducing therapeutic hyperthermia in both colon cancer and hepatocellular carcinoma cells.

Summarizing, our work highlighted the versatility of polydopamine-based nanostructures in modulating cellular activities through both antioxidant capability and light-responsive mechanisms. The high biocompatibility and biodegradability of PDNPs, along with their multiple “smart” properties, make these nanoparticles an extremely promising platform for human healthcare applications.

INMA Impulso CSIC Universidad Zaragoza

Funded by the European Union NextGenerationEU
Plan de Recuperación, Transformación y Resiliencia
Gobierno de España Ministerio de Ciencia, Innovación y Universidades
Gobierno de Aragón