ICG-loaded mesoporous nanohybrid (Nd-doped Hydroxyapatite/ Fe3O4) for photonic/magnetic hyperthermia and photodynamic therapy

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Background:
Multimodality nanoplatforms play a crucial role in advancing medical interventions by integrating multiple functionalities into a single system. However, issues like intricate production processes and biocompatibility persist. Herein, a facile synthesis of a biomaterial-based mesoporous nanocarrier, HAp:Nd+SPIONs@$mSiO_2$, loaded with the near-infrared (NIR) emitting dye indocyanine green (ICG) is reported.

Methods:

HAp:Nd nanoparticles were synthesized via combustion methods. Thereafter, commercial SPIONs and HAp:Nd were integrated within a mesoporous silica via a modified Stöber approach. HAp:Nd+SPIONs@$mSiO_2$ nanoplatform was characterized for particle size, porosity, and luminescence using TEM, BET, and luminescence spectroscopy. The synthesized nanoplatform was further loaded with ICG dye and the loading efficiency was analyzed via UV-Vis spectroscopy. Photonic and magnetic thermal heating of the ICG-loaded nanoplatform was also analyzed along with the photo-stimulated ROS generation ability. Finally, cytotoxicity and therapeutic analysis was performed in vitro using triple-negative breast cancer cells (MDA-MB-231).

Results:
The nanohybrid with ~100 nm average size, comprised of Nd-doped hydroxyapatite (HAp), Fe_3O_4 superparamagnetic iron oxide nanoparticles (SPIONs), and mesoporous silica, exhibiting magneto-luminescent properties. The mesoporous structure was loaded with ICG as a model drug (4.3 µg/mg of nanoparticles) where a pH-dependent release was observed. The nanocarrier demonstrated dual functionality by generating heat through magnetic and photonic stimulation, as well as producing reactive oxygen species (ROS) upon excitation with 808 nm light. In vitro bioevaluation on aggressive triple-negative breast cancer cells (MDA-MB-231) showed the high biocompatibility of nanohybrid with and without ICG and exhibited significant toxicity after irradiation of NIR light. Noticeably, the nanohybrids also exhibit the ability to monitor temperature changes via Nd^{3+} associated NIR luminescence.

Conclusions:
The nanoplatform integrates clinically relevant components, highlighting its potential for translation from the laboratory to clinical applications. The developed nanohybrids, with combined NIR-mediated photothermal and photodynamic effects, magnetic photothermal capabilities, and NIR/MR imaging, offer promise in addressing cancer heterogeneity and improving conventional treatments with reduced side effects.