Abstract

Cancer is one of the leading causes of death worldwide. According to the World Health Organization (WHO), approximately 10 million deaths were attributed to cancer in 2020. With an aging population and lifestyle factors, the number of cases is expected to continue rising. Despite significant advancements in science, technology, and societal development, cancer remains a significant global health challenge due to the limitations of conventional therapies, such as poor specificity, severe side effects, and limited efficacy against metastatic disease.

This study focuses on developing novel multifunctional nanoconjugates using liquid metal (LM) and ionic liquid (IL) as soft materials for advanced cancer theranostics. The research emphasizes photothermal therapy (PTT), immunotherapy, and bioimaging, by using the impressive photothermal conversion of LM- and carbon nanohorns (CNHs)-based nanoconjugates. The nanoparticles were chemically functionalized with biomolecules and fluorescent dyes to improve stability, dispersibility, and biocompatibility. These nanoparticles exhibited exceptional photothermal conversion efficiency and selective tumor ablation under near-infrared (NIR) laser irradiation, with less side effects. Additionally, surface modification with immunostimulants enabled synergistic integration of PTT and immunotherapy, enhancing therapeutic efficacy. Building on this, we also introduced smart magnetically driven nanoconjugates by loading magnetic IL. These nanoconjugates demonstrated precise magnetic responsiveness, providing a solution to the low targeting of the enhanced permeability and retention (EPR) effect and enabling controlled drug delivery and localized photothermal effects. This innovative approach expanded the versatility of soft materials in cancer treatment. *In vivo* mice tumor model confirmed the therapeutic potential of LM and CNHs-based nanoconjugates, achieving significant tumor regression, enhanced bioimaging, and excellent biological safety. This work advances the field of cancer nanomedicine, providing a multifunctional platform for nanotheranostics and targeted therapies.

Keywords: cancer, nanoparticles, soft material, near infrared laser, photothermal therapy, immunotherapy, chemical functionalization