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Nanotheranostics in cancer diagnosis and treatment

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Cancer, the most deadly disease has been known to mankind since ancient times. Advance technologies and chemotherapeutics have been developed to fight cancer. Cancer is not just one disease but it is the collection of related diseases. In recent years, nanotheranostics has gained much interest in providing effective personalised treatment against cancers owing to its multifunctionality feature that integrates both diagnosis and therapeutics in one platform. Theranostic nanomedicine provides malignancy imaging and controlled and targeted delivery of diagnostic and therapeutic agents, i.e. targeted drug release and multiple imaging modulation. Tumour microenvironment shows EPR effect and different physicochemical characteristics in comparison to normal healthy cells, such as acidic pH, hypoxia, active efflux pumps, hyperthermia, altered redox potential and overexpressed molecular biomarkers. Considering all these factors, the design and development of nanotheranostics have been made. For example, light-responsive graphene combined with an anticancer drug (doxorubicin) and a pH-sensitive disulphide-bond linked hyaluronic acid forms a nanogel, which can help in diagnosing and treating cancer. This type of nanoparticles presents many features, such as thermal therapy, chemotherapy, real-time non-invasive imaging and light-glutathione-responsive controlled drug release. Nanotheranostics can deliver therapeutic drugs to tumour tissues and cells through passive and active targeting by effectively increasing drug concentration in tumour-specific sites with improved efficacy, with less effect of toxicity to healthy cells. There are various nanoparticles used for cancer therapy, such as lipid-based nanoparticles, polymer- and dendrimer-based nanoparticles, noble metal-based nanoparticles (such as gold and silver), semiconductor nanoparticles, carbon nanotubes, metal oxide nanoparticles, metal-organic frameworks (MOFs), and upconverting nanoparticles (UCNPs). Nanoparticles carrying contrast agents, such as fluorescent dyes, gadolinium-based probes and radionuclides have been used for optical imaging, magnetic resonance imaging (MRI), computed tomography (CT), single-photon emission computed tomography (SPECT), positron emission tomography (PET), photoacoustic imaging (PA) and ultrasound (US) imaging. These molecular imaging techniques have shown a great potential for detection and diagnosis of diseases and monitoring the physiological or pathological processes of organisms at the cellular and molecular level, including gene expression, signal transduction pathways, tumour cell metabolism, proliferation, apoptosis, tumour hypoxia, perfusion and angiogenesis. Nanotheranostics monitor the drug action site, drug distribution in the body, the characteristics of drug release and the therapeutic efficacy; and also for cancer diagnosis and treatment with low invasiveness nanotheranostics can be used. Gold, iron oxide nanoparticles, fullerene and multi-walled carbon nanotubes can be used as photothermal theranostic agents. Real-time monitoring helps in treatment planning and dosage adjustment, which further helps in providing personalised treatment. More advancement in nanotheranostics could take place in the upcoming years but as of now, no current nanotheranostics formulation has been approved for translation into clinical practice.

Keywords: Cancer, Nanotheranostics, Tumour microenvironment, Diagnostics, Therapeutics, Personalised treatment, Theranostics, Nanomedicine, Tumour, Malignancy

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