Application Of Quantum Dot Fluorescent Dyeing Technology in Tumor Detection

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Abstract. As a high-incidence disease, the tumor poses a huge threat to human health today. The timely and efficient detection of tumors is of great significance to improving the cure rate and improving people's health. Quantum dots have advantages of high fluorescence intensity, good stability and good biocompatibility, providing a new research approach for the detection of tumor markers. This paper reviews the application of quantum dots fluorescent dyeing technology in biosensing, imaging, tumor detection and treatment, which provides a reference for the development of tumor detection technology.

Keywords: Quantum dot; Fluorescent dyeing technology; Tumor.

1. Introduction

The quantum dot technology originated in 1974. Quantum dots (QDs) can be used in light-emitting devices, solar cells, display devices and other fields, and are one of the research hotspots in the field of new materials. Quantum dots are kinds of nanocrystalline grains, whose particle size is between 2 to 20 nanometers. Due to the characteristics of electrons and electron holes and the continuous energy level structure, they form a discrete energy level structure with molecular characteristics, and emit through excitation. Fluorescence, which exhibits a narrow half-peak width of the fluorescence spectrum and excellent monochromatic performance, has extraordinary applications in the fields of biosensing, biomarking and imaging. Quantum dot technology has a clear spectrum and small overlap when performing biomarkers, which greatly improves the efficiency and sensitivity of detection. The current research hotspots of this technology focus on the discovery and application of green, low-toxicity, and higher luminous efficiency quantum dot materials to avoid the biotoxicity of nanomaterials and achieve better biocompatibility.

2. Advantages of QDs

Quantum dots have a simple synthesis method, high fluorescence performance, high luminous intensity, strong photostability and rich colors to meet complex biological systems, low biological toxicity, adjustable emission spectrum, long circulation time in vivo, long fluorescence lifetime, and strong tissue penetration ability (far-infrared emission), the emission wavelength of quantum dots can be tuned by controlling the size and composition of quantum dots [1]. Compared with traditional organic fluorescent dyes, organic dyes can only absorb light of a specific frequency, and cannot use light of the same frequency to excite multiple dyes to produce fluorescence of various colors, while quantum dots have a wide excitation band. The same color of light can be used to simultaneously excite quantum dots of different sizes to obtain fluorescence of different wavelengths and colors. Its fluorescence intensity and stability are about 100 times that of ordinary fluorescent dyes, which can

support the long-term at the same time, it has good biocompatibility, can perform specific connection, has little harm to organisms, and can carry out labeling and detection of living bodies.

3. Applications in Biomedical Fields

3.1. Classification and Tracing

Quantum dots can be integrated into the cell body by coupling with biological macromolecules to realize long-term fluorescent labeling of living cells, proteins, DNA and other living substances, making QDs show great application prospects in the fields of clinical diagnosis and drug screening. At the same time, it also has a good performance in the diagnosis and treatment of diseases, and has applications such as therapeutic carriers, drug delivery, and nanomedicine.

3.2. Biosensing

Quantum dots have relatively stable thermal and chemical properties, good biocompatibility and excellent electrical conductivity after modification, and can be well applied in the field of biosensing. Theoretically, it is possible to realize biosensing through the optical signal of quantum dots to reflect the biological signal of protein [2].

3.3. Bioimaging Applications

The fluorescence lifetime of quantum dots is long, and the luminous range of light can cover part of the near-infrared region, which is conducive to penetrating the biological tissue layer for deep tissue imaging, and can greatly reduce the interference of biological tissue due to autofluorescence. Therefore, quantum dots have unique advantages and great potential for bioimaging applications (both in vivo and in vitro) [3].

In vivo fluorescence imaging can realize the application of molecular imaging technology in vivo, and can more accurately observe gene expression and cell activities in living organisms, thus providing the most complete information about the biological effects of treatment or disease progression, which is of great importance to medicine and biology. research is of great significance. Nowadays, in vivo bioluminescent imaging is realized by using high-performance fluorescent probe technology. Due to the need to apply in vivo, it is necessary to use fluorescent probe materials with low toxicity, strong hydrophilicity, high efficiency, structure and fluorescence stability, and also has excellent biocompatibility and is easy to combine with biomarkers.

Quantum dots with near-infrared (NIR) luminescent properties are used for biological in vitro fluorescence imaging. Quantum dots with high photostability, excellent fluorescence efficiency, strong tissue penetration ability, and good biocompatibility are selected. Compared with in vivo imaging, in vitro imaging is less demanding on biological toxicity and has a wider range of options. Common faults of hydrogen compressor.

4. Applications in Oncology

4.1. Applied to Tumor Diagnosis

4.1.1 Applied to detection

Tumor markers have been used clinically for many years, providing effective information for cancer diagnosis and curative effect observation. Quantum dots, as a new type of fluorescent probe, are inevitable for the development of science and technology to replace traditional fluorescein. The application of quantum dots to mark tumor markers will definitely improve the accuracy of early immune detection of cancer, and has attracted more and more attention.

At this stage, whether it is tumor diagnosis or treatment, the identification of tumor targets is the key. Many specific proteins on the surface of tumor tissue and genes specifically expressed in tumor tissue can be used as targets for tumor detection. In a study of ovarian cancer, researchers used

quantum dots coated with thioglycolic acid to successfully detect human ovarian cancer cells in vitro. Sun et al. used CEACAM8 antibody-bound quantum dots to perform immunofluorescence imaging on cervical cancer HeLa cells and achieved good results [4]. Quantum dots can be used for cancer imaging and pathological detection at the same time, and breast cancer can be diagnosed by combining the two. Early detection of breast cancer invasion can be realized through two-color imaging. The special fluorescent properties of quantum dots make the imaging effect better.

4.1.2 Applied to Imaging Technology

Traditional imaging such as X-ray and CT are difficult to detect early tumors, and it is difficult to accurately locate and diagnose qualitatively. Quantum dots can be used as fluorescent nanoprobes for non-invasive in vivo fluorescence imaging; early diagnosis and good imaging effects can be provided, providing accurate and comprehensive tumor diagnosis. The development of molecular imaging requires not only advanced imaging equipment, but also the development of new and efficient imaging probes.

At present, in the application of nano-probes, many magnetic nano-probes have entered clinical practice on MRI imaging one after another. In terms of CT and PET imaging, nanoprobes made of various noble metals and isotopic materials are mainly in the basic research stage. Optical-related imaging technologies such as optics and photoacoustic imaging have the advantages of non-destructive and high-resolution, and will provide technical support for the development of a new generation of biomedical imaging. Fluorescence, Raman, photoacoustic and other nanoprobes will also develop in the direction of targeting, high sensitivity, multimode and non-toxic with the advancement of modern technology. Optically correlated nanoprobes will be combined with simple, non-destructive, real-time and portable operating systems to better serve the clinic.

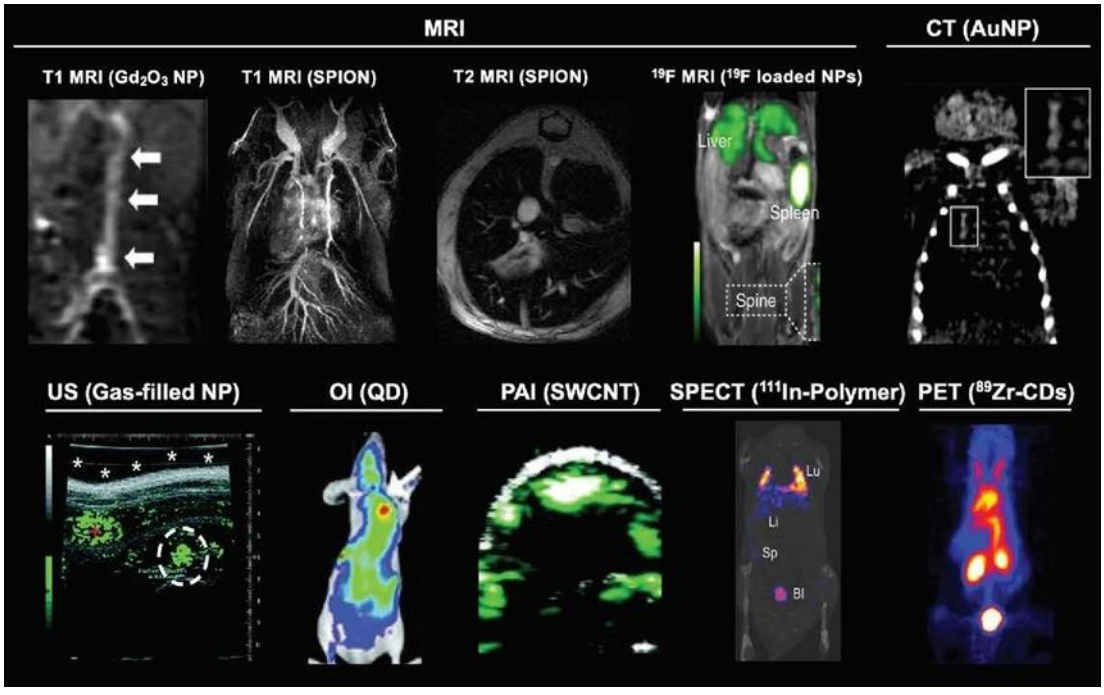


Fig. 1 Representative images of the main modalities used to image different nanomaterials [5]

Table 1. Summary of the properties of the imaging modalities used for nanoparticle imaging discussed in this review. PC = preclinical scanner; C = clinical scanner [5]

Imaging technique	Spatial resolution	Depth penetration	Sensitivity	Relative cost
MRI	≤0.1mm(PC) 1-2mm(C)	No limit	mM–mM	€ € €
CT	≤0.2mm(PC) 0.5-1mm(C)	No limit	mM	€
SPECT	0.5-2mm(PC) 5-12mm(C)	No limit	<pM	€ €
PET	1-2mm(PC) 3-6mm(C)	No limit	fM	€ € €

4.2. Used in Tumor Therapy

Disadvantages of traditional medicines. Traditional drugs for treating tumors have many disadvantages, including poor water solubility, poor targeting, low bioavailability, many adverse reactions, and high prices. Traditional cytotoxic drugs still enjoy a certain status in clinical practice due to their use value, but because of their therapeutic Due to the limitations of the disease and the harm of adverse reactions, newly developed drugs, molecular targeted drugs and anti-tumor herbal medicines are gradually replacing their position in some fields and become the first choice for treatment.

Quantum dots can be effectively combined with anticancer drugs. Quantum dots can provide targeting, and can intuitively, quickly and accurately obtain information about the distribution, release, and pharmacodynamic mechanism of drugs in cells, and can play a role in drug delivery, and can accurately bring drugs and imaging agents to tumor sites [6]. Nano-drugs and drug delivery carriers have received more and more attention in targeted tumor therapy due to their smaller size. Quantum dots not only have the advantages of general nanoparticles, but also can monitor their distribution and metabolism in organisms in real time after administration, which provides a convenient and effective analysis method for nanomedicine and drug delivery carriers.

Quantum dots have potential toxicity and scavenging ability in biological systems. Quantum dot-coupled phagocytosis can kill tumor cells. With the continuous improvement of the preparation technology of functionalized quantum dots, multifunctional nanoparticles with targeting, tracing, diagnosis and treatment are constantly emerging [7], and the common and personalized toxicological evaluation of functionalized quantum dots has been become required.

Quantum dots can also be used in surgical tumor surgery. Quantum dots can accurately locate sentinel lymph nodes, axillary lymph nodes, etc., and help surgeons directly observe and accurately locate and resect to provide guidance. Qi-Long Wu constructed c(RGDyk) cyclic peptide-modified liposome-encapsulated quantum dots, quantum dots c(RGDyk)-Lip had a particle size of 175 nm, and had good particle size and fluorescence stability in physiologically relevant media; quantum dots-(RGDyk)-Lip not only had a low toxicity, and can effectively target C6 tumors for fluorescence imaging. Animal experiments have shown that quantum dot-c (RGDyk)-Lip can efficiently target orthotopic tumor-bearing rat brain glioma after intravenous injection, making it emit strong fluorescence to guide precise surgical resection [8].

5. Conclusions

The ultimate goal of improving the sensitivity of biomarker assays is to achieve ultrasensitive detection of single molecules or particles. The current laser-induced fluorescence detection method has reached the detection level of single molecules, but the detection system is complex and has not yet reached the purpose of daily common analysis. In order to improve the detection sensitivity, it is necessary to find a marker with stable and long-term signal, easy labeling, safety and sensitivity. Quantum dot technology for nanomaterials seems to fit these criteria. With its unique labeling

characteristics, quantum dot technology will surely become the cutting-edge technology for biomolecular detection in the future. Receptor, enzyme-substrate) reaction principle provides a more advanced method. At the same time, it will also greatly promote the rapid development of biological imaging technology and biopharmaceutical technology, and bring great progress to the diagnosis and treatment of diseases.

It has biological safety hazards, the toxicity mechanism is not completely clear, and it has certain cytotoxicity and genotoxicity; it needs in-depth research to formulate a strict treatment and evaluation system to make the clinical application of quantum dots scientifically standardized. Personalized medical diagnosis and treatment have great potential, can provide patients with more accurate treatment plans, can realize the integration of molecular imaging and treatment, and can be applied to all stages of tumors. The detection of tumor markers has many advantages such as economy, convenience, and speed, and has important guiding significance in the early screening, diagnosis, evaluation of curative effect, and prognosis evaluation of malignant tumors. Quantum dots are used as molecular imaging agents in tumor therapy to locate early tumors in real time, detect tumor metastasis, identify and quantify a series of tumor molecular markers and monitor tumor prognosis. They have shown great potential and are worth further exploration and development. Only by further improving the synthesis and surface chemical modification of quantum dots and reducing possible chemical Toxicity, in order to better apply quantum dots to biological research. Compared with traditional fluorescent dyes, quantum dot multiple staining shows an excellent linear relationship in the detection of various tumor markers, with low detection limits, good stability and reproducibility, and provides a wide range of clinical application prospects for multiple detection. It is the future development direction of early diagnosis and treatment of malignant tumors.

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