Science Arena Publications
Specialty Journal of Agricultural Sciences
Available online at www.sciarena.com
2016, Vol, 2 (2): 1-4

Applications of Quantum dots in Cancer Treatment

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Abstract: Today in the field of medical science, cancer has become the most discussed and most concerned subject. Due to the increasing death rate all over the world researches nowadays are mostly based on finding some cures for cancer and also understanding the causes of cancers. Quantum dots are the nano-sized crystals used for imaging and therapy of cancers because of their striking characteristic of high photobleaching resistance. Quantum dots (Qds) proved to be more successful various cancer imaging followed by therapies. Multicolor Qds could be used to detect multiple markers at a time. These crystallized nanosensors with more enhancements and more efforts could be made an accurate source for cancer treatment, in the form of drug carriers and photobleaching protection agents. They are also capable of certain toxic effects that are yet to be understood to overcome. Once proved to be more successful they would also be made available for medical treatments at affordable costs.
Key words: Quantum dots, HER-2, monoclonal antibodies

Introduction

A In Pakistan, the death rate due to cancer has increased at an unstoppable rate in the past few years. The two major life taking cancers common in Pakistan are the breast cancer and the lung cancer. According to statistics released by International Agency for Research on Cancer (IARC) in 2012, number of people with newly diagnosed with cancer were 148,000, the risk of cancer in people before age 75 was 11.8% and death due to cancer were 101,000. According to 2013 data on cancer, female deaths due to breast cancer were more than 16,000 and this number was 7100 in 1990. Deaths from mouth cancer in Pakistan in 2013 were more than 3000 and approximately 2500 women died due to stomach cancer in 2013. Deaths due to cancer all over the world were almost 8.2 million in the year 2013. The major hurdle in the treatment of cancers is the lack of early diagnosis and detection of tumors and timely drug delivery to destroy tumors. In cancer treatment nanotechnology has played a pivotal role in the form of quantum dots (Qds). Quantum dots are actually the semiconductor nano-sized crystals that have the ability to emit light when exposed to a light source [1]. They have excellent properties like:

- They act as optical sensors for visualizing.
- Have increased brightness when excited by light.
- Resistance towards biochemical alteration in the body that may otherwise render anything unable to work or fluoresce.
- Can be easily detected and are highly tunable.

Development of these nanocrystals was a major breakthrough in the history of nanotechnology. A quantum dot has the diameter ranging from approximately 2-10 nm where it consists of 200 -10,000 atoms equivalent to the size of a protein [2]. The fluorescence of Qds-based multipurpose probes carries high sensitivity for simultaneous cancer cells imaging and targeted cancer therapy [6]. Photodynamic cancer therapy, an emerging cancer treatment uses photosenitizers and light energy to cause death of the cancerous tissues. Due to the unique light absorbing property of Qds, they were used Samia et al. [8], they used the photosensitizing

agents bioconjugated with Qds of size in range of 1-6 nm that allowed the photosenitizers to get activated at the wavelength of light at which photosensitizing agents alone could not have absorbed and would not have created reactive oxygen species that destroyed surrounding cancer tissue. Thus Qds having been the most active agents excited by light energy have astonishing contribution in cancer imaging and therapy.

Applications of Quantum Dots:

Tumor Detection:

I. **Ovarian Cancer:** In cancers mostly the biomarkers are used for detection of tumors. In the case of ovarian cancer carbohydrate antigen (CA125) is being used as a biomarker for its detection. The ability to view or visualize ongoing processes that occur in living beings is almost of no value in clinical diagnosis, yet it remains impossible to visualize cellular processes due to conventional imaging practices and unavailability of suitable fluorescent markers [2]. Wang et al. [3] used Qds with a maximum fluorescence emission wavelength of 605nm to detect carbohydrate antigen (CA125) in different types of ovarian cancer specimens with high sensitivity and accuracy [2]. The use of Qds and their striking properties have opened new ways for advanced molecular and cellular imaging as well as for highly sensitive bioassays and ovarian cancer diagnostics [2].

II. **Breast Cancer:** Presently HER-2 (Human epidermal growth factor receptor) is being used as a biomarker in the detection cancer tumors, yet this tumor detection can be enhanced by using conjugated multicolor quantum dots as was done by Yezhelyev et al.[4] in which they used multicolor quantum dots for at the spot and timely detection of 5 different markers for breast cancer namely HER-2 (Qd-HER-2), ER (Qd-ER), PR (Qd-PR), EGFR (Qd-EGFR) and mTOR (Qd-mTOR) in cells of breast cancer (MCF-7 and BT474) [2]. Cancer identification by the molecular expression might be necessary to classify different subtypes of cancer.

Multicolor Qds: are the quantum dots that can track multiple molecular marker targets at a time.

III. **Prostate Cancer:** Diagnosis of this cancer is done by using prostate-specific antigen (PSA). Detection of prostate tumors using PSA is not precise because of the ability of PSA to detect only on site tumors, whereas these prostate tumors have the ability to leave their site and get distributed in various other parts, moreover the elevated PSA levels could always be false positive, which means they might have elevated levels but also in those men with no prostate cancer at all. Conjugation of PSA with Qds could lead to the precise imaging of tumors and could also detect their distribution in case of malignant tumors. Fluorescent probe conjugated with PSA provides a specific and sensitive tool for early prostate cancer imaging *in vivo*. With Qds probes conjugated to a PSMA monoclonal antibody (Ab), Gao et al. [5] used this marker containing Prostate Specific Monoclonal Antibody (PSMA) conjugated to Qds and achieved sensitive multicolor fluorescent cancerous cells imaging under *in vivo* conditions [2].

Integrated Functionalities:

- **Imaging and therapy:** They range in diameter from 2-10 nm and when encapsulated becomes about 5-20 nm in diameter. Qds can serve as the structural scaffold and an agent for imaging of tumors. Moreover, small molecules of anti-tumor drugs can also be incorporated into the core of Qds for targeted therapy of cancer tumors.
- **Tags for other drug carriers:** Drug carriers are mostly made of poly (lactic-co-glycolic acid) and polyethyleneimine polymers [7]. Such carriers of drugs are not much efficient due to the lack

of imaging of drugs transportation [7]. Labeling these carriers with Qds can help in visualizing and keeping the record of the drugs delivered by carriers.

- **Protection:** Drug carriers are more prone to biochemical alterations which make them useless, and thus the tagging of these drug carriers with quantum dots make them resistant to photobleaching as Qds themselves are photobleaching resistant.

Conclusion:

Quantum dots so far have proved to some extent to be of useful to mankind. With more efforts and more researches on these quantum dots a new wave of precise and complete cancer eradication is awaiting in the near future. Moreover, with the adoption and little more enhancements of these small imaging nanocrystals and drug delivery agents most of the fatal cancers and other fatal diseases like HCV, HIV, anthrax, rabies etc could be overcome. Due to their extraordinary properties of excitation by light energy and precise detection of tumors and targeted drug delivery, they could replace the conventional cancer therapy barriers involving late detection and improper drug delivery. Conjugation of biological components with quantum dots also proves them to be advantageous in providing specific treatment. Currently they are widely being used in vitro conditions due to their cytotoxic effects that they may cause in humans because they are made of heavy metals and it is feared that they may have cytotoxic effects if not flushed out of the body after therapy. Although these imaging and therapy agents might be expensive at start but once all the barriers have been overcome, then they would be available at an affordable expense.

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