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Advances in combination of quantum dots and nanotechnology-based carrier systems against cancer - A critical review

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Abstract: The challenge for the delivery of chemotherapeutic agents is a safe administration of drugs which will only affect the cancer cells. The dose is tumor microenvironment and these doses are effective while ensuring minimum cytotoxicity. Current therapeutics has some limitations like the insufficiency of specificity in delivery. The development of different nanoscale carriers has potential in delivering cancer therapies as well as imaging, and also overcome both tumor and systemic barriers. These nano-carriers provide specific and targeted delivery along with imaging.

Key words: Quantum dots, Cancer, Drug delivery, Carriers for cancer treatment

Introduction

Currently, the pharmaceutical industry has developed formulations in profusion, although because of their decreased bioavailability and limited efficacy due to cell membrane permeability and low aqueous solubility. There are some constraints regarding conventional formulations like poor solubility, toxicity and undesirable drug release pattern (1). While great progress has been made for getting better survival by reducing incidence and mortality rates but, still cancer is a main public health problem in the world (2). Diagnosis of cancer in the primary stage is one of the major challenges, even there is a possible curative treatment. For early identification and management of cancer new technologies are required, which leads to considerable improvement (3).

One of the interesting advancements in modern technology is quantum dots (QDs) development, as a modification of medicine to nanocrystals which have abundant potential utilization due to their distinctive chemical and optical properties, where they are used to check the *in-vitro* and *in-vivo* luminance of the molecules (4).

In vivo, molecular and cellular imaging of QDs is much studied because of it is novel electronic and optical properties. QDs current application includes cancer diagnosis, early detection of primary tumor like ovarian cancer, pancreatic cancer, prostate cancer, breast cancer and, as well as distant metastases and regional lymph nodes (5). Currently, Quantum dots (QDs) nanomaterials that create a major influence on research in many fields across the physical, chemical, and biological sciences. Quantum Dots sole electro-optical property has been largely motivated within the molecular and bulk semiconductor regimes. At present, for the fabrication of optical probes for cellular and biological sensing, tissue or whole-body imaging, the QDs makes an impact (6).

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Quantum dots are luminescent semiconductor crystals nanometer in size and because of their highly dense structure and size they have special physical and chemical properties, Hence, on chemical composition and size of quantum dots, they produce different wavelengths over a broad range from visible to infrared. Finally, Quantum dots use improves the clinical diagnostic tests in cancer in its primary stages. The size of colloidal QDs is approximated to the individual biomolecule; they are bright, long-lasting photo stable. To identify tumor cells, water-soluble quantum dot complex have been used. In spite of their significances, the bests materials for synthesis of QDs are cadmium sulfide (CdS) and cadmium selenide (CdSe) and these are highly lethal in nature (7).

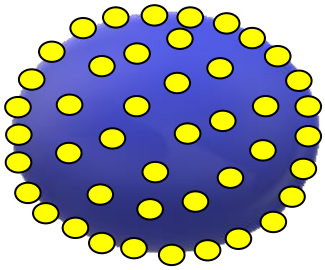

Fig. 1. Structure of Quantum dots

Quantum dots are semiconductor nanocrystals (Figure 1). The Core is consisting of semiconductor material cadmium selenide. Shell is covered with the coating of ZnS encompass the semiconductor core which improved its properties and the encapsulation of cap with the help of double-layer QDs by different materials e.g. In aqueous buffers (7-9) silica helps in improving solubility (8). At present, in certain fields as shown in table 2, QDs proceed with to make an influence like the development of optical probes for cellular and biological sensing, tissue or body imaging. The modulation of QD luminescence can be attained in various ways as they have a particular reaction to the existence of target analyte. These include, but are not necessarily limited to charge transfer (CT) quenching, fluorescence resonance energy transfer (FRET), electrochemiluminescence (ECL) and bioluminescence resonance energy transfer (BRET). The CT reactions are strongly influenced by the photoluminescence (PL) of QDs, while QDs have been established to be excellent acceptors in BRET and donors in FRET (9). QDs exhibit electronic properties and unique luminescence characteristics which include continuous and broad absorption spectra, high light stability and narrow emission spectra. Depending on the material bandgap QDs absorb white light and then re-eject a specific color in a few nanoseconds (10). QDs are the first nanotechnologies to be incorporated and are widely foresee to eventually find application in a number of clinical products and commercial consumers (11).

1. Cytotoxicity of Quantum dots

QDs are cytotoxic in nature to some level. The cytotoxicity is depended upon the different parameters like QD exposure route, surface chemistry, size, dose, coating bioactivity. There are also a win over the toxic impact of residual organic molecules on target cells (12). Group III-IV of quantum dots has been outlined to exhibit acute cytotoxicity and shown a large probability of the use of an optical probe *in vivo* (13). There are some constraints of QDs, which include: difficulties in high-throughput synthesis, high reaction rate, long reaction time and poorly controlled growth rate. Hence, the type of core material used toxicity of QDs is dependent as shown in table 1 (14).

Drug delivery of Quantum Dots with anticancer drug

Nanoparticles in Drug Delivery

Nanomedicine is defined as the implementation of nanotechnology to diagnosis, disease treatment, monitoring, and control of biological systems (National Institutes of Health, USA). Recent cancer therapies have some side effect because significant toxicities are common in the process of treating cancer tissues, chemotherapeutic agents also damage healthy tissues. The nanocarriers can help to overcome both problems like the risk of killing the healthy tissues and the dosage of the drug users can be decreased. Polymeric nanoparticles, quantum dots (QDs), micelles, silica nanoparticles, dendrimers, molecular conjugates, liposomes, and ultrasound microbubbles are examples of nano systems that are used for such purposes (33). These nanoparticles or nanomedicine varying in size from 10 nm to 1000 nm. The

properties of nanoparticles differ dramatically; these are high surface /volume ratio, improved solubility, and multifunctionality. Nanoparticles are reported to improve the bioavailability, retention time and solubility of the bioactive agents associated with them (34).

With the usage of nanotechnology, drug delivery agents like nanoparticles can deliver agents such as DNA, antisense RNA and anticancer drugs and accumulation of agents at previously "unreachable" target sites such as blood-brain barrier is possible. Nanoparticles of all sorts can permeate through capillary walls or gaps. And their movement in the extracellular matrix and uptake by the cells is easier than the microparticles because of the size (35). There are several types of carriers that can serve as drug carriers. Liposomes, polymeric nanoparticles, dendrimers are the mostly used controlled release systems. Their size can be scaled down to nanometers range (Table 3).

Table 1. Selected studies on QDs toxicity

Quantum Dots	Model used	Toxic effects and Stability attribution	Reference
CdSe/ZnS–SSA **(0.1–0.4 mg/mL)**	EL-4 lymphoma cells	Cytotoxic effect: 0.1 mg/mL transformed cell proliferation. Cells were largely non-viable at 0.4 mg/mL. QD stability attributed to Quantum dot capping material.	15
CdSe/ZnS– mercapto undo acetic acid (MUA) (**1–2 µM)**	WTK1 cells[a]: (Human lymphoblastoid cell line that over-expresses a mutant form of p53)	Within 2h the 2µ MQD–COOH induced DNA damage, due to the toxicity side of QD hydrophilic coating and Upon prolonged 12h incubation DNA repair.	16
CdTe (**0.01–100 µg/mL)**	Rat pheochromocytoma cells, murine microglial cells	10 µg/mL cytotoxic and QD stability attributed to QD core deterioration and release of Cd ions.	17
CdSe/ZnS amphiphilic poly (acrylic acid) polymer-coated Quantum Dots, and conjugated to MPEG Quantum Dots **(Injections; ~180 nM Quantum dot, ~20 pmol Quantum Dot/gm animal weight)**	Mice	Amphiphilic coating on Quantum Dot leads to QD stability and to the area of deposition there are no signs of necrosis at a particular space.	18
Avidin-conjugated CdSe/ZnS Quantum Dots **(0.5 to 1.0 µM)**	HeLa cells	No effect on cells/tissues	19

Table 2. QD-Based Medical Applications

Applications	Description	References
Diagnostics	• Her2 (hairy-related 2) are detected on SK-BR-3 breast cancer cells by recruiting humanized anti-Her2 antibody, a biotinylated goat antihuman IgG, and streptavidin-coated QDs	20
	• Immunofluorescence labeling of mortalin by using QDs gives various staining patterns between normal and cancer cells	21
	• Identification of ovarian cancer marker CA 125 in various species using streptavidin-conjugated QDs	22

Imaging	• Imaging skin and adipose tissues in mice by injection of water-soluble QDs • Using oligomeric phosphine-coated QD, mapping sentinel lymph nodes at tissue depth is done that emit in the near-infrared region • Using QDs tracking diffusion dynamics of glycine receptors	23 24 25
Drug delivery and therapeutics	• To retain drug molecules and neurotransmitters inside a mesoporous silica nanosphere-based system Surface-modified CdSQDs were used as chemically removable caps • QD–siRNA conjugates are used for screening of siRNA sequences and monitoring RNAi delivery	26 27
Biomedical research-QDs in relation to neuroscience	**QD-GlyR**- Target neurons to investigate a specific neurophysiological process (QDs to track individual glycine receptors and analyze their lateral dynamics in the neuronal membrane) **Antibody-conjugated quantum dots**- Performed the specific labeling of neurons and glia cells **Tagged nerve growth factor (βNGF) to QDs**- Investigate the QD nanostructure's potential to assess the neurite outgrowth **QD-anti-TrkA**-TrkA receptor with transport by GFP- Immobilized QDs were conjugated with NGF, activate Trk receptors, and initiate neuronal differentiation in PC12 cells **Tagged cell surface proteins with a specific peptide (acceptor protein) that can be directly biotinylated as a target for streptavidin-conjugated quantum dots**- Specifically, label and track AMPA receptors on cultured hippocampal neurons	28 29 30 31 32

Table 3. Types of nanocarriers adapted for drug delivery.

Form	Approach	Properties
Polymeric micelles	Amphiphilic block copolymers form a micelle with hydrophilic shell and hydrophobic core.	Suitable carrier for water insoluble drug Self-assembled, biodegradable. Ease of modification Targeting potential
Dendrimers	With regular patterns and repeating units radially emerging hyperbranched polymers	Biodistribution and pK can be tuned High structural and chemical homogeneity Ease of functionalization, high ligand density Multifunctionality
Liposomes	Self-assembly Structures composed of lipid bilayers	Amphiphilic, biocompatible Ease of modification Targeting potential
Viral nanoparticles	Protein cages, which are multivalent, self-assembled structures	Surface modification by mutagenesis or bioconjugation multivalency Specific tumor targeting, multifunctionality, biological compatibility Defined geometry and uniformity
Carbon nanotubes	Carbon cylinders composed of benzene rings	Water-soluble and can be made biocompatible through chemical modifications Multifunctionality

FDA has approved 30 nanoparticles for clinical use and liposomes were more successful compared to the others. Multi-functionality is the major advantage of nanoparticles. QDs; are able to carry drugs, imaging agents and affinity ligands to achieve traceable targeted drug delivery. With the help of this multi-functionality, the distribution effect of the drug can be observed in real-time (36).

a. Liposomes

Liposomes are self-assembled colloidal particles consist of amphiphilic molecules that are composed of both nonpolar and polar components. In the spherical structure of

liposomes with the nonpolar parts of the molecule containing the nonpolar environment and the polar components containing the polar environment. There are numerous lipid bilayers are present in the colloidal structure of liposomes, with multilamellar liposomes containing multiple lipid bilayers and unilamellar liposomes containing one lipid bilayer. For delivery, both polar and non-polar compounds are encapsulated by liposomes due to their amphiphilic nature (37). Due to their similarity with cell membranes in composition and structure, liposomes are boom for drug delivery applications. In addition, liposomes are formulated with non-immunogenic, non-toxic, natural and biodegradable amphiphilic molecules (38). Liposomes rapidly clear from the bloodstream. For drug delivery applications, liposomes can carry both hydrophilic and hydrophobic molecules; hydrophilic molecules are encapsulated in the hydrophilic core and Non-aqueous molecules embedded in the lipid bilayer. The functionalization of liposomal surface with poly (ethylene glycol) tethers to impart increased stabilization (39). Liposomal surface can also be tailored with ligands for active targeting. Doxil was the liposomal anticancer formulation authenticated by the Food and Drug Administration (FDA, USA) in 1995. The pegylated biodegradable liposome was used to encapsulate doxorubicin and became the first liposome-based treatment for cancer (Doxil) (40).

Liposomes loaded with quantum dots are used as a label, which significantly increased the assay sensitivity by encapsulating multiple quantum dots in a single liposome and, therefore, amplifying the analytical signal (41). The drug and QDs were mainly located in the bilayer membrane and inner core of the liposomes, respectively. The mean diameter of Spherical vesicles ~140 nm was formed. QDs were completely encapsulated by the vesicles (42). Liposomes loaded with QDs had high biocompatibility and low toxicity in Caco-2 cells as shown in figure 2. QDs are useful materials as tracers of liposomes *in vivo* applications (43).

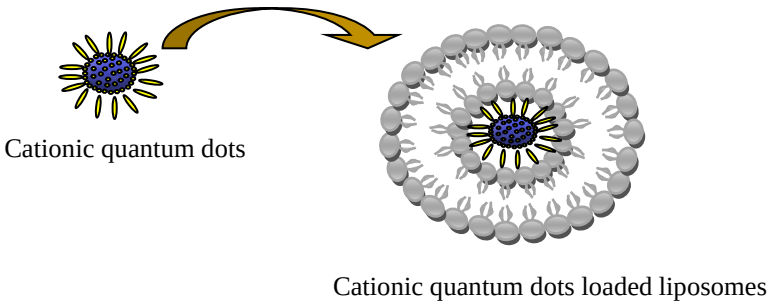

Fig. 2. Liposomes loaded Quantum dots

b. Micelles

Micelle is the self-assemble amphiphilic molecules, structured with a hydrophobic core and a hydrophilic exterior. For multiple reasons, micellar structure lends itself well to drug delivery applications. Diameters of micelles are less than 100 nm, allowing them to participate in extravasations through the fenestrations in tumor vessels and limiting their uptake by the MPS/RES system. The immediate recognition and subsequently increase circulation time is protected by hydrophilic surface characteristics of micelles (44). Hydrophilic corona protects hydrophobic drugs during transport to the tumor site, and during transport hydrophobic drugs can be loaded into the core of the micellar structure as shown in figure 3 (45).

The PEGylated phospholipid micelle provided an effective nano-platform for encapsulating organic PbSQDs as contrast agents in NIR fluorescent imaging. These nanoparticles were used for sensitive *in vivo* live animal imaging as well as *in vitro* cell imaging. The toxicity of the PbSQDs has been greatly reduced by the micelle encapsulation, as this indicating that the encapsulation provides effective protection over the organic substances (46).

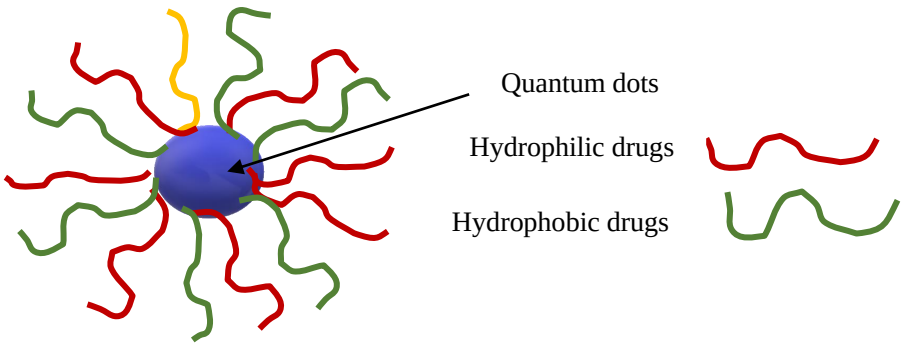

Fig. 3. Micelles loaded quantum dots

c. Dendrimers

Dendrimers are highly branched molecules that display a high degree of monodispersity and well-defined structure. Targeting ligands and molecules such as folic acid are used on the surfaces of the dendrimers for functionalization. Dendrimer's multifunctional core can be used to encapsulate drug molecules and protected by its extensive branching as shown in figure 4. The Silva research group demonstrate successfully that aqueous synthesis of hybrid nanocomposites of CdS, ZnS and CdS: ZnS QDs with different DAB dendrimer generations. Nanocomposites DAB-ZnS QDs show absorption in the 250 to 260 wavelength range and a fluorescence emission in the 430 to 450 nm wavelength range (a Stokes Shift about 200 nm) (47).

Lemon and their team reported the preparation and characterization of dendrimer encapsulated CdS nanoparticles (DE-CDS). Dendrimer first acts as a nanoreactor that sequesters Cd2+ ions, and then after reaction with S2- it stabilizes the resulting CdS nanoparticles by preventing agglomeration. Because the size of the nanoparticle (or quantum dot, QD) is related to the size (or generation, G) of the dendrimer pattern used to prepare it, and because the size-dependent optical properties of QDs and the absorptive and emissive properties of the QDs are a function of the generation of the dendrimer pattern used to prepare them. In addition, the several reactive groups on the surface of the dendrimer can be used to leave the composites soluble in essentially any solvent, including water, organic solvents, fluorous phases, and even supercritical fluids, and as synthetic handles for attachment of ligands to direct binding of the composites to surfaces, DNA, biological ligands, and other targets (48).

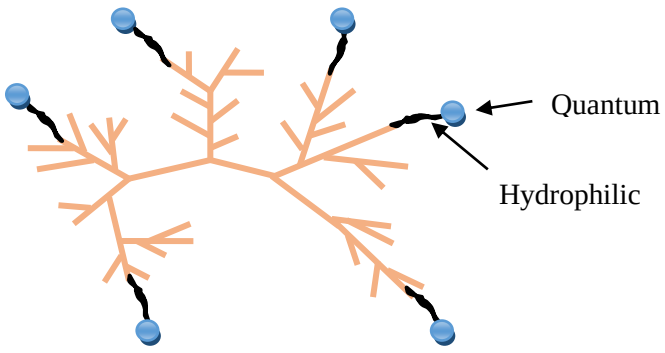

Fig. 4. Dendrimers loaded Quantum dots

d. QDs mediated delivery system MWCNT delivery system

For the fabrication of multiwall carbon nanotube-nanocrystal heterostructures, a novel strategy is shown. In a simple, uniform, and controllable manner different quantum dots (QDs) with narrow size distributions were covalently coupled to carbon nanotubes (CNTs) and silica-coated CNTs as shown in figure 5(49).

For novel chemotherapeutic drug delivery-platforms, carbon nanotubes (CNTs) have emerged as viable candidates. It is possible to conjugate QDs to CNTs, making it possible to exploit their novel attributes in the domain of cancer theranostics (diagnostics and therapy). Carbon nanotubes (CNT) and quantum dots (QDs) are the two nanoparticles, where QDs are gaining momentum as imaging molecules with life science and clinical applications. CNTs have unique photothermal properties that allow them to be used in conjunction with near-infrared radiation and lasers to thermally remove cancer cells (50). CNTs show tumor-specific property, by passive accumulation at tumor sites through an enhanced permeability and retention (EPR) effect (51).

Conjugating CNTs to QDs

CNTs have a large chemically active surface area; a characteristic which offers the support of semiconductor nanoparticles eg., QDs. Either direct attachment or an intermediate molecule such as polymer that has previously been conjugated to CNT or QD is used to link QDs to the CNT surface. Despite the approach used, the bonds linking the two nanostructures will be either covalent or non-covalent (52). The covalent bonding conjugation of QDs to the CNT may be achieved using acid solutions that functionalize the surface of these materials to provide a suitable platform for the CNTs to form covalent bonds with QDs. In a covalent bonding, a linker like 1-ethyl-3-(3-dimethyl aminopropyl) carbodiimide hydrochloride (EDC) may be employed between the functional group of the CNTs and QDs. This simply sticks to the surface allowing weak intermolecular interactions between the CNT and the QDs (53). The attachment of the QDs to the CNT surface generated more intense fluorescence emission spectra in comparison to the direct attachment approach as shown in table 4.

Table 4. Example of the materials used for the attachment of CNT to QDs.

Type of CNT and QDs	Material used for conjugation	Final products
MWCNT37-CdTe	PEI	MWCNT-PEI-CdTe
MWCNT36-CdSe	SiO2	MWCNT-SiO2-CdSe
SWCNT34-CdSe	PBASE	SWCNT-PBASE-CdSe
SWCNT7-CdSe	Str	SWCNT-Str-CdSe
MWCNT37-CdSe	SDBS	SWCNT-SDBS-CdSe
MWCNT35- CdSe	Mercaptoacetic acid	MWCNT-Mercaptoaceticacid-CdSe

Abbreviations: MWCNT, multiwalled carbon nanotubes; SWCNT, single-walled carbon nanotubes; Case, cadmium selenide; CdTe, cadmium telluride; PEI, polyethyleneimine; SiO2, silica; PBASE, 1-pyrene butyric acid *N*-hydroxysuccinimide ester; QDs, quantum dots; Str, streptavidin; SDBS, sodium dodecylbenzene sulfonate

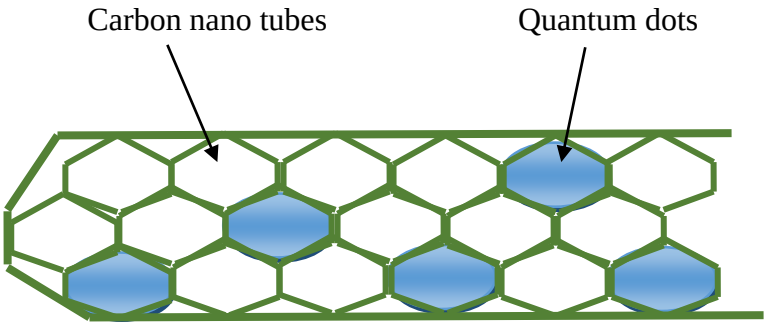

Fig. 5. Conjugation of both carbon nanotubes and quantum dots.

e. Quantum dots and cell-penetrating peptide-mediated drug delivery system.

Cell-penetrating peptides (CPPs) has progressively gained popularity for delivering macromolecules into live cells. CPPs indicate transition capability through biomembranes (54). CPPs are positively-charged short peptide sequences, rich in lysine or arginine proteins. These peptide sequences are also recognized as protein transduction domains (PTDs), protein translocation domains, membrane translocating sequences and Trojan peptides (55).

The first CPP was discovered in 1988, it was found that the trans-activating transcriptional activator (TAT) from human immunodeficiency virus 1 (HIV-1) could be efficiently taken up from the surrounding media by numerous cell types in the culture. A protein transduction domain is present in HIV-1 TAT (Trans-Activator of Transcription) that allows it to translocate across the cellular membrane, and this process is known as protein transduction. It was also found that TAT could efficiently be taken up by various cell types (56).

Table 6. Examples of some common cell-penetrating peptides (CPPs), their origins and sequences.

CPP Name	Origin	Sequence
TAT	Protein-derived from HIV-1 TAT protein	GRKKRRQRRRPPQ
Penetratin	Protein-derived from Drosophila antennapedia	RQIKIWFQNRRMKWKK
Transport	Chimeric peptide of galanin and mastoparan	GWTLNSAGYLLGKINLKALAALAKKIL
Pep-1	Chimeric: HIV-reverse transcriptase/SV40 T- antigen	KETWWETWWTEWSQPKKKRKV

CCP, cell-penetrating peptide

Conjugation of quantum dots with cell-penetrating peptides

For effective intracellular delivery of fluorescent proteins, including yellow fluorescent protein (YFP) and the multichromophoric b-physio-erythrin complex (b-PE), CCP functionalized QDs have been used. With direct microinjection delivery, QD-proteins entered into live cells, while bypassed the endolysosomal system. This resulted in a more homogeneous distribution of conjugates throughout the cytosol whereas conjugates of QD-peptide-protein were circulated within the endosomal compartments (57).

1. Tat peptide conjugated quantum dots (Tat-QDs)

Ruan and his research group have used Tat peptide-conjugated QDs (Tat-QDs) as a model system to investigate the intracellular transport and cellular uptake of nanoparticles into live cells. The Tats (cell-penetrating peptides) have been examined for their efficiency to deliver QDs into living cells (58). For the employment of Quantum dots in living cells for dynamic fluorescence imaging, the researchers used a spinning-disk confocal microscope at 10 frames per second. In agreement with the recent work of Dowdy and co-workers, results indicated that the peptide conjugated QDs are internalized by macro-pinocytosis (59). However, it is interesting that the internalized Tat-QDs were trapped in intracellular organelles and tethered to the inner surface of vesicles. To an asymmetric perinuclear region called the microtubule organizing center (MTOC), it was found that the QD-loaded vesicles can be actively transported by molecular machines (such as dyneins) along microtubule tracks. (60).

2. QDs with endosome-disrupting Coatings

Recently a new category of cell-penetrating quantum dots (QDs) was developed, on the basis of the use of multivalent and endosome-disrupting (endosomolytic) surface coatings. By direct ligand connecting with the QD surface, excessed branched copolymer ligands like PEG-grafted polyethyleneimine (PEI-*g*-PEG) were able to encapsulate and stabilize luminescent quantum dots in hydrophilic solution. QDs might enter in the cell membranes and distort endosomal organelles in living cells due to positive charges and a "proton sponge effect". In this grafted PEG segment, PEI and other polycations were used to drastically decrease the toxicity and enhance the nano-particle stability and biocompatibility. The Quantum dots were swiftly internalized by the process of endocytosis shown by Cellular uptake and Imaging studies (61).

f. QDs and polymeric delivery system

The proposed novel drug delivery system of QDs fabricated with anti-cancer agents and coated with biocompatible polymer represents a potential platform to deliver tumor-targeted drugs and document the delivery process. This

leads to the development of multifunctional nanoparticle probes based on semiconductor quantum dots (QDs) for cancer targeting and imaging in living animals. Recently, the encapsulating luminescent QDs with an ABC triblock copolymer (the amphiphilic polymer) are linked to tumor-targeting ligands and functionalized drug-delivery. The growth of prostate cancer in mice indicated that the QD probes assemble at tumor site, by enhanced permeability as well as retention at tumor sites. The studies showed that sensitive and multicolor fluorescence imaging of cancer cells under *in vivo* circumstances can be achieved by both subcutaneous injection of QD-tagged cancer cells and systemic injection of multifunctional QD probes. The results raised new possibilities for ultrasensitive and multiplexed imaging of molecular targets *in vivo* (62). Recently, ZnO quantum dots (QDs) were combined with biodegradable chitosan (N-acetylglucosamine) for tumor-targeted drug delivery. In this method, Non-toxic water-dispersed ZnOQDs (with long-term fluorescence stability) were fabricated by a method of chemical hydrolysis, Chitosan encapsulation with anti-cancer drug. Here, The stability of the QDs is enhanced by chitosan polymer. This study aspect in the direction of the design of a new drug release carrier, which represents a prospective platform to provide tumor-targeted drugs along with the documentation of the delivery process (63).

g. QDs encapsulation in viral vector and non-viral vector

Incorporation of Semiconductor Quantum dots (QDs) like (CdSe/ZnS) into viral particles provides a new paradigm for the design of intracellular microscopic probes and vectors. Several strategies were explored for the inclusion of QDs into viral capsids; those functionalized with polyethylene glycol (PEG) can be self-assembled into viral particles with minimal release of photoreaction products as well as enhanced stability against the prolonged irradiation (64). With the help of radical polymerization, in situ synthesis of less cytotoxic ZnO quantum dot-based nonviral vectors with the double activity of delivering plasmid DNA and labeling cells was fabricated i.e., by tailoring the surface of ZnOQD with poly (2-(dimethylamino) ethyl methacrylate (PDMAEMA). ZnO QDs were modified by the polycations and are capable of making denser plasmid DNA into nano molecules (Qdot-plexes) loaded with ZnOQDs capable of emitting strong yellow luminescence under UV light. An effective shifting of plasmid DNA into COS-7 cells by Qdot - plexes with much lower cytotoxicity, meanwhile allows real-time imaging of the gene transfection (65).

Conclusion

Combined delivery of QDs with anticancer drug have enormous attention as the most precious and promising candidates of drug delivery, imaging, and targeting. Different drug carriers are used for combined delivery of quantum dots and anticancer drugs which build them, magnificent volunteer, for *in* gene/drug delivery, *in vivo* bioimaging, and cancer detection. The development of the nanocarrier drug delivery system has the capability to deliver cancer therapies to overcome both systemic as well as tumor barriers and provide specific and targeted delivery along with imaging.

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