**Original Review Article****DOI: 10.26479/2019.0502.24****QUANTUM DOT: AN EMERGING NANO-CRYSTAL FOR CANCER  
DIAGNOSIS AND THERAPY****Mohit Kashyap<sup>1</sup>, Aishwarya Tiwari<sup>1</sup>, Khushboo Arya<sup>1</sup>, Vijay Laxmi Saxena<sup>1,2\*</sup>**

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**ABSTRACT:** Cancer is one of the leading active diseases and burning issue in the world nowadays. In every six death, one is responsible due to cancer globally. The biomedical presently deals cancer with following treatment surgery, chemotherapy, radiation therapy, immunotherapy, targeted therapy, hormone, and stem cell transplant. But present treatments have various negative side effects on healthy tissues. Symptoms such as loss of hair, loss of appetite, nausea and vomiting, mouth sores, and rashes on skins etc. The new era, therapies free from side effects needed to treat cancer for mankind. Nanotechnology may provide the suitable way to treat active diseases especially in cancer. Nanotechnology offers to target directly to cancerous cells and neoplasms. Quantum dot is one of the emergent nanotechnology which mechanism is based on its optical and electric property to diagnose and treat cancer better. QD is direct target the tumor which causes cancer and removes the cancerous cells. Due to the small size of QD it targets many of the area before working on the tumor cells. It is the one of the challenge to make Quantum dots mechanism more effective for curing cancer in biomedical field. This article summarises the all available to date studies outcomes, using procedures and effects of the quantum dot mechanism in cancer therapy. It's role in the improved mechanism of finding accurate effected targets, drug delivery with lesser side effects.

**KEYWORDS:** Mutagenesis, Toxicity, QD (Quantum dots), Cancerous cells, Neoplasm.**Corresponding Author: Dr Vijay Laxmi Saxena\*Ph.D.**

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**1. INTRODUCTION**

In the world Cancer is the second top cause of death above only by cardiovascular diseases.

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Abnormal cells are dividing in the uncontrolled and random way then Cancer occurs in the body. More than a hundred of millions of cells are present in our body. All Cancer begins with cells by the changes in cells and group of cells. This primary tumour receives metastatic potential and spread to other body sites, which causes metastasis and finally death. Mostly cancers grow from primary tumours [1]. Cancer is a major health problem in the world. One often is suffering from these types of diseases in the world. In the USA 1,665,540 people suffered from Cancer, and 585,720 of them died due to this disease by 2014 [2]. Surveys during 2011-2012 suggest that 39.6% of women and men are suffered from cancer. In India, 14.5 lakh people living with cancer, over 7 lakh new cases arising every year and 5, 56,400 deaths due to cancer. It indicates that 71 % death which is related to cancer between the age group of 30 to 60. Lung, colorectal, pharynx, stomach, head and neck, and liver were the most common type of cancer diagnosed among men while the five common type of cancer diagnosed among women were breast, ovary, lip and oral cavity, lung, and cervix[3]. The primary symptoms to diagnose cancer disease are fatigue, weight loss, pain, skin changes, change in bowel or bladder function, unusual bleeding, a persistent cough or voice change, fever, lumps or tissue masses [4]. Abnormal cell division in lungs, sarcoma, pancreatic etc. leads to cancer.

### **Types of cancers**

**Lung Tumor:** - This cancer is a malignant lung tumor characterized by uncontrolled cell growth in tissues of the lung. Lung tumor also is known as carcinoma of the lung or pulmonary carcinoma that derives from epithelial cells. Most of the cancers that start in the lung, known as primary lung cancer. Lung tumours are neoplastic tumours of the lung. The reason for 90% of lung cancer is cigarette smoking. So, high prevalence of smoking is a big reason to born lung cancer. Lung cancer is most common cancer worldwide. [5]

**Sarcoma Cancer:-** A Sarcoma is a rare kind of cancer which is different from the much more common carcinomas because they happen in a different kind of tissues. These tumours are most common in the bones, muscles, tendons, cartilage, and blood vessels, nerves, fat, of your arms and legs, and they can happen anywhere. Sarcoma cancer arises from the cells of mesenchymal origin in virtually every tissue of the body; they can differentiate along a number of tissue lineages, such as adipose, muscle, fibrous, cartilage, or bone.[6]

**Pancreatic Cancer:-** Pancreatic cancer occurs when the cells in pancreas begin to multiply out of control and form a mass. Signs and symptoms of the most common form of pancreatic cancer may include loss of appetite, yellow skin, abdominal or back pain, unexplained weight loss, light-colored stools, dark urine. The pancreas is a gland about 6 inches long that is shaped like a thin pear lying on its side. The wider end of the pancreas is called the head, the middle section is called the body, and the narrow end is called the tail. The pancreas lies between the stomach and the spine. [7]

**Ovarian Cancer:** - Ovarian cancer starts in the ovary and may spread to the lining of abdomen, lungs, liver etc. Prognosis of ovarian cancer is poor because cancer metastasizes early and it is not

properly diagnosed until the disease is advanced. Ovarian cancers originate from ovarian surface epithelial cells, was undermined. Majority of serous ovarian cancers have its origin in the malignant tubal epithelium, while endo-metrioid and clear cell ovarian cancers develop most likely from endometriosis [8].

**Kidney Cancer:** - Include smoking; obesity and use of NSAIDs are the main reason for Kidney Cancer. Prognosis of this type of cancer depends on type and stage of cancer, patient's medical history. Renal cancer or kidney cancer is the cancer of kidneys. Tumours confined to the kidney have a better prognosis than tumours that have spread outside the kidney. Kidney cancer is a group of different type of cancer that occurs in the kidney so kidney cancer is not a single disease. Each of these different types of kidney cancer can have a different histology, have a different clinical approach, can respond differently to therapy and is caused by a different gene[9].

**esophageal cancer:-** Esophageal Cancer arises from the esophagus the food pipe that runs between the throat and the stomach. This type is also known as esophageal cancer. esophageal squamous-cell carcinoma and esophageal adenocarcinoma are the main two type of disease. Esophageal cancer typically begins in the mucosa of the esophagus and spreads through deeper tissue layers, i.e. the submucosa, muscle layers, and serosa. Simultaneously there may be lymphatic or hematogenic progression [10].

### **Treatments for cancer**

**Surgery:-**Surgery is the oldest type of therapy. In this removal of a tumour and surrounding tissue by the operation [11]

**Side effects:-** Swelling and Bruising around the site of surgery, drainage from the site of surgery, Pain, Infection, Fatigue, Lymphedema etc. [12].

**Radiation Therapy:** In this use, the high dose of Radiation to kill cancer cells and shrinks a tumour. In this therapy used X-ray to see inside the body. [13].

**Side effects:** Skin problems (dryness, itching, blistering, Peeling), Fatigue, long-term side effects (return to second cancer), pelvis. [14]

**Chemotherapy:** - Drugs use for cancer treatment. It's often called "Chemo". Chemo can kill cancer cells. Cure, Control, Palliation are three main goals of this therapy [15]. Their side effects are Fatigue, Mouth Sores (mucositis), Hair loss, Constipation, Nerve Damage (Neuropathy), Diarrhea, Vomiting [16].

**Immunotherapy:** -Use Person's Immune System to fight Cancer, this Process work in two ways: (1) Stimulated the Immune system of the body to attack cancer cells. (2) Used Man Made Immune system components of proteins [17].

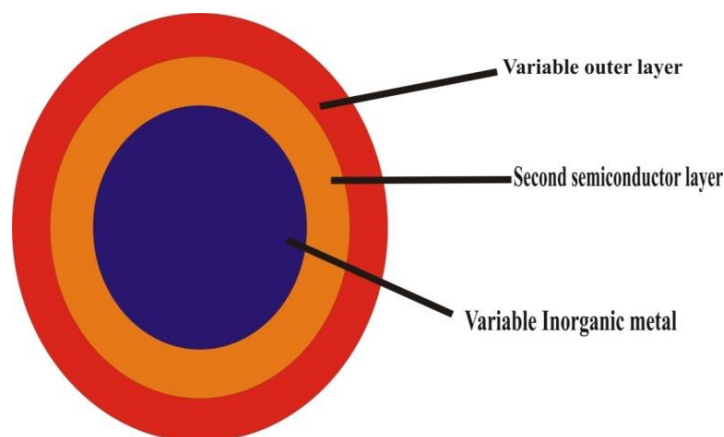
Side effects: Fever, Chills, Nausea, Vomiting, Loss of appetite, Fatigue [18].

**Targeted therapy:** -The drugs work as (1) Prevents the signal that reason of cancer cells and divide them. (2) Stop the developing of cancer cells. (3). Kills and remove the cancer cells. [19].

Side effects: Hand-foot syndromes, Itching, Dry skin, Rash, Sores around the fingernails and toenails, the problem in hair growth, Black or Yellowish body (effective parts) [20].

### Quantum Dot (Arising Approach for Cancer Treatment)

Quantum dot discovered by Alexie Ekimov and Louis E Brus in 1980 during own research work. Quantum Dots are tiny semiconductors with excitons confined in all three spatial dimensions. These are semiconductors whose conductivity lies between that of bulk semiconductors and those of discrete molecules [21]. Quantum dot is inorganic semiconductor nanocrystal which possesses unique luminescent properties. QDs are composed by group II and VI (CdSe or CdTe) or group III and V (InP and InAs. QDs are one of the most promising nanocrystals with unique optical and chemical properties due to their special size and surface effect [22]. Quantum dot worked as an efficient fluorescent probe in cancer detection and treatment. Due to size, high stability, non-photo bleaching and water solubility made them a unique fluorophore in place of conventional organic dyes [23]. Quantum dots may allow the surgeon to map sentinel lymph nodes and perform a complete surgical resection because Quantum dots can be helpful to identifying potential molecular biomarkers for cancer diagnosis, treatment and prognosis. QD is ideal donors of fluorescence energy transfer and photodynamic therapy studies. For synchronous cancer diagnosis, targeting and treatment of cancer or tumour, multifunctional QDs have effective materials. But toxicity properties of QD remain the major barrier to clinical approach [24]. The size of Quantum dot lies between 2-10 nm and highly reactive due to high surface/volume ratio. Semiconductor Quantum Dot is nanometer crystal structures has the property of photophysical and high fluorescence quantum yields. Due to quantum confinement effects, quantum dot has the unique property of photophysical as a colloidal nano crystalline semiconductor [25].



**Figure 1:** Structure of Quantum Dots (i) Variable outer layer depending on needed surface finalization (e.g. peptides, antibodies) (ii) Semiconductor layer (e.g. ZnS) (iii) variable inorganic metal (e.g. CdTe, CdSe )

Quantum dot is an important part of nano medicine toolbox. This provides the best treatment for many diseases. Today nanotechnology is the best way of detection of diseases .Quantum dots famous

for cancer detection. Quantum dot used for nano diagnostics, imaging, targeted drug delivery and phototherapy. In vivo and vitro, many researchers produce many types of research for show detection of cancer. But based on mice treatment due to toxicity nature of quantum dot. Toxicity nature is the major drawback of cancer treatment by the Quantum dot. So we keep attention to remove toxicity method for cancer treatment.

## **2. MATERIALS AND METHODS**

### **Mechanism of QD for targeted drug delivery**

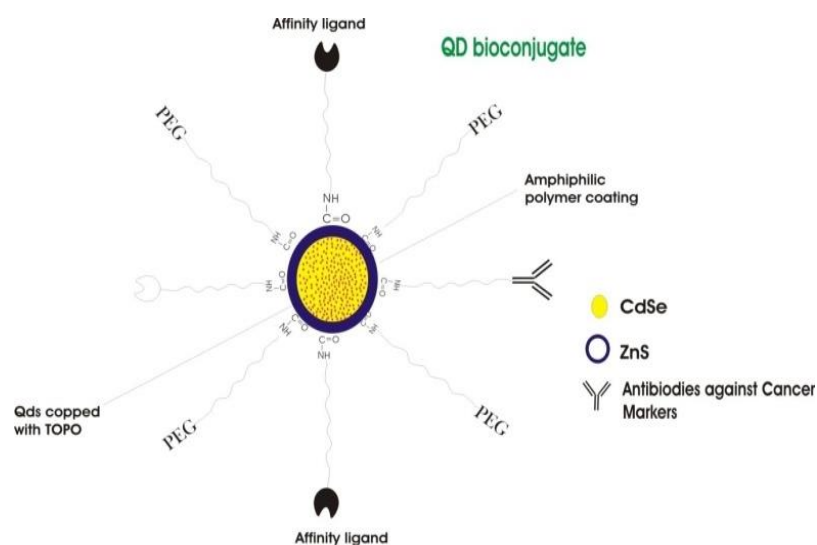
- i. The nanoparticles (QD) can reduce the side effect of the drug because QD as carrier modifies the effect of the original drug to enhance the water solubility or get target thereby enhance the efficacy of anticancer [26].
- ii. QD's have the unique mode of controlling and releasing the drugs. Nano-carriers for drugs can significantly extend the effectivity of drugs at limited concentration, deliver at fewer intervals and lower doses and reduce side effects and the suffering of patients.
- iii. By modifying antibodies, aptamer, folic acid and other biological molecule drug-loaded nanocarriers targeted delivery of drugs to specific suffer organs [27].
- iv. Because the property of adhesion and small particle size, it is possible to extend the effect of the drug, increase contact criteria of drug and improve the bioavailability and absorption of drugs [28].
- v. Improved stability and utilization of drugs by Nanoparticles carriers because they can prevent the rapid degradation of drugs by the digestive enzymes in the body. [29].
- vi. QD-polypeptide nano gel in drug delivery functions has the possibility for treatment in cancer diagnosis, imaging, and therapy [30].
- vii. Drug-loaded nanocarriers improve absorption effects of the drugs in cells because can alter the mechanisms of membrane transport and enhance the permeability of drugs in bio-film [31].
- viii. No reaction with drugs, high drug loading capacity and encapsulation efficiency, appropriate preparation and purification method, good biocompatibility and low toxicity, certain mechanical strength and stability and appropriate particle size and shape, a longer residence time in vivo.
- ix. A quantum dot (nano robots) makes real ideal soldiers for target specific actions due to the property of the ability to overcome problems such as drug resistance, lack of selectivity and solubility [32].

### **Mechanism of Quantum Dot in Cancer treatment**

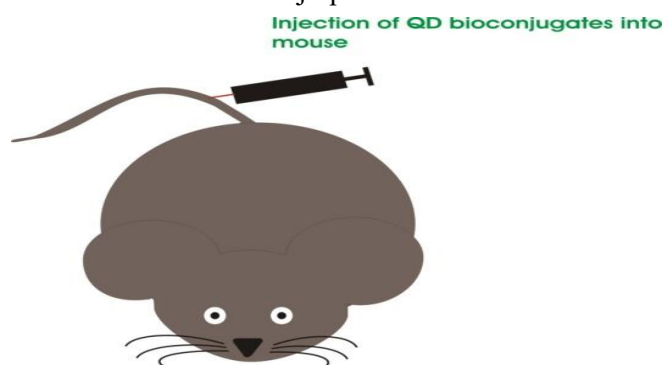
In earlier method surgeons detect cancer by colored dye and then remove a malignant tumour and surrounding lymphatic vessels and nodes but the lymphatic vessels and nodes near a tumour may be healthy, in this case, their removal is harmful. In this method surgeons take a picture of a tumour and surrounding effective area then treatment start based on the picture seen. It is very harmful because a lack mistake is enough for side effect generation. The main problem with this method is

the using dyes are might quickly, so we take an image for future observation, but it does not give the present view of nodes so doctor work depending on the picture status [33]. After the study of the quantum dot, we have details that due to small size quantum dot have the toxicity nature. If we inject quantum dot medicine by injection in the body, then it detects a cancer tumour and removes this tumour, but study reveals that this treatment has a toxicity problem occurs during the process which is very harmful to the body. So removal of this toxicity problem, can be a better method for cancer treatment. Phytochemicals with QD produce a non toxic biocompatible Quantum Dot, which are very useful in cancer treatment as well as medical field. Phytochemicals are basically generated by nature like plants and fruits [34]. Quantum dot generally has the approach for targeting to tumour and cells. Quantum dot conjugated by the peptide, antibody, inhibitor, the drug usually called affinity ligands so due to this property it is used to treat against Cancer as the figure bellow. Multifunctional QDs usually employed for targeting tumour cells. QDs are conjugated to various affinity ligands (peptide, antibody, inhibitor, drug etc.) specific for the tumour cell biomarkers [35].

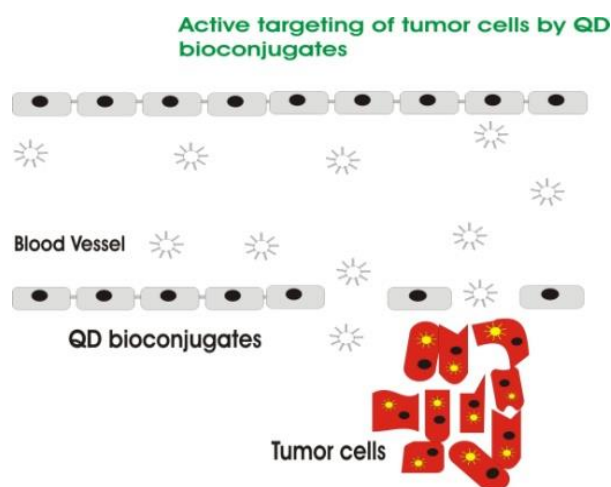
**a.**



**b.**



**c.**



**Figure 2:-Various steps in employing QDs for *in vivo* diagnosis of cancer.**

- (a) Formation of QD bio conjugates, (b) Intravenous injection of QD bio conjugates into a mouse,  
(c) Active targeting of tumour cells by QD bio conjugates

### **Cytotoxicity of Quantum Dot**

Quantum dot is useful for imaging and sensing in the biomedical field. Due to some constituents are heavy metals (Cd and Hg) in quantum dot raising toxicity [36]. In previous Vitro studied we obtain Quantum Dot is toxic in nature. This toxicity generates due to many Factors like including size, coating bioactivity color, the dose of QDs, capping materials, color, the dose of QDs, surface chemistry, and processing parameters. Interaction of QDs with intracellular Components, Desorption of free Cd (QD core degradation), free radical formation, and Examination of QD toxicity in a hepatocyte culture model showed that exposure of core CdSe to oxidative environment causes decomposition and desorption of Cd ions. These mechanisms during synthesis and processing played an important role in subsequent toxicity [37]. Quantum dot's toxicity is arisen due to oxidation of the nanoparticles core/shell material, leading to the release of free cadmium. This is the main reason which make is nonuseable in the human body. Cadmium ions have been shown to bind thiol groups on critical molecules in the mitochondria and cause enough stress and

damage to cause significant cell death [38]. It is observed that Cadmium-containing QDs can kill cells in culture, but QDs are toxic to cells; It must be toxic to humans [39]. The toxicity of Quantum dot type depends on its composition, surface chemistry, dose, size and structure. It is a big problem of Quantum dot. The main toxic effects of Quantum dots on respiratory system divide into two parts: (I) In vivo, lung injury and inflammation and potentially long-term. (II) In vitro, including reduction of cell viability, genetic material damage and disordered immune cell reactions [40]. So this can say that QDs have great prospects, but the toxicity of QDs cannot be overlooked. In biological applications (cancer imaging, targeting and PDT treatment) QD could be harm for the other cells together cancer cells of the body due to the presence of degradation products which produce immune responses with the components in blood. The principal reason for toxicity (I) The release of Cd ions and heavy metals due to oxidation of nanoparticles core/shell material which responsible for interrupting the normal cell activities. (II) Photosensitized production of reactive oxygen intermediates (ROI). (III) Toxicity of capping materials (Thioglycolic acid). (IV) Quantum dot and their capping materials may be immunogenic, which could result in both dangerous immune reactions in subjects, and could also render the QDs ineffective as a result of antibody binding.

### 3. RESULTS AND DISCUSSION

QDs are one of the most encouraging nanocrystals with unique optical and chemical properties due to their special size and surface effect. Quantum dot works as an efficient fluorescent probe in cancer detection and treatment. Due to size, high stability, non-photo bleaching and water solubility made them a unique fluorophore. QDs are a notorious topic due to toxic nature. The toxicity generates due to Cd, small size, and its reactive nature. It can be minimize If we do process or method by which we can control to make the QDs size at particular type where they have not highly reactive. Coating to control their toxicity means by making QDs to size at which they are not highly reactive and toxic i.e. when it is injected in body it should not harm to body and should not react with blood, blood cells or tissue, as It is known that It has toxic effects and can be much harmful to the body. Quantum dot with phytochemicals deals by Laser mechanism can be made the detection process possible because Laser detects the exact tumor of cancer according to the property of quantum dot. If this method which detects and remove a tumor, after the removal of tumor quantum dot molecule tryspreads over in the body so carefully, injected quantum dot molecule should be removed by laser equipment from the body before it get scattered. Phytochemicals are natural product and with mixing with QD make it biocompatible. So these studies state that biocompatible QD mechanism is considerable application for treatments of diseases, mainly tumour or cancer therapy due to special size and surface effect. By controlling the reactivity, toxicity and the size of QDs It can be useful in biotechnology and biomedical application.



#### 4. CONCLUSION

Biocompatible QDs have all the properties for cancer cells treatment. Today nanotechnology helps biosciences and future generations also. The main highlights are its nano size, high reactivity, good surface area which provides more effective results to analysis and treats any diseases in short and less time. Toxic nature of QD needs proper attention to be modified and improved. But biocompatible Quantum Dots plays significant role not only in cancer disease but also in the treatment of active diseases. This mechanism provides different ways of application in biomedical fields.

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#### CONFLICT OF INTEREST

Authors declare that there are no conflicts of interests.

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