

A Review on Applications of Nanoparticles in Cancer Treatment

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Abstract

Cancer has become the leading cause of death. It is caused by disorder in the division and growth of cells. It can be treated after the confirmation of growth of cancerous cells. Conventionally it is done by X-rays or CT scans. Then the genes are destroyed or damaged or by controlling the blood supply to other genes. Now, advancements in nanotechnology have enabled the physicians to treat the cancer. In this review, we will discuss the recent developments in the cancer nanotechnology and how in a better way cancer can be treated in its early stages.

Keywords: Cancer, nanoparticles, drug delivery, active target delivery, passive target delivery

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INTRODUCTION

Nanotechnology is the study, control, fabrication and application of materials at 1 to 100 nm scale length. As we move towards smaller scale, the surface to volume ratio increases. This change in surface to volume ratio causes a material to behave differently at smaller scale. So, nanomaterials exhibit entirely different properties than they do at micro level. Hence they have unique applications. Some of the examples are:

- Insulators change into conductors,
- Opaque materials turn into transparent,
- At room temperature, solids change into liquids,
- Non-reactive materials become catalyst [1–5].

Nanoparticles are now being widely used in many applications. One of its vast and major applications is its tremendous use in biology and medicine. For such purposes, silver and gold nanoparticles are used due to their unique properties such as stability, conductivity, antibacterial and catalytic properties. Nanoparticles are designed for different purposes. Depending on the nature of use, their size ranges from few nanometers to several hundred nanometers. Nanoparticles used for drug delivery have different sizes and shapes, e.g. spherical, branched, tube, branched, liposomes, fullerenes, shells and emulsion etc.

Drugs are inserted into nanoparticles by entrapping, attaching on surface or encapsulating them.

Cancer is a major cause of death recently. It can be treated by surgery, chemotherapy and radiotherapy. A laser pulse having wavelength suitable for the absorption of the diseased tissues than the surrounding healthy tissues is used for treatment. Time period for the pulse is also confined in order to maintain the temperature rise. More targeted heating has become possible due to the light absorbing dye. Now, light absorbing nanoparticles have been developed. These particles are not harmful for biological tissues hence more target delivery is possible without harming the near healthy tissues [6–12].

Nanocarriers are the most efficient way of drug delivery. They increase the effectiveness, efficiency and remedial level for a long period of time by reducing the toxicity. They are also capable of increasing the stability and also the solubility of the drugs. They are also good for combined therapies, multifunctional drug delivery and for the applications of therapy and diagnosis simultaneously [13–21].

CANCER DETECTION

Conventional Method

Cancer is detected conventionally using X-rays or CT scans by observing the growth or some

physical change of the organ. But this method is not very suitable because it is not very sensitive and cancer is detected only when there is enough growth of cancerous cells. Often after this detection, there are little chances of treatment as the cancer has grown in such an advance stage [22].

Using Nanotechnology

Since the size of cells is few microns while the size of nanoparticles is of nanoscale, so nanoparticles can enter the DNA and gene and if there is any defect in gene, it can be detected very easily. In this way cancer can be detected in its very early stage and hence can be treated in time [1, 23–25].

TYPES OF NANOPARTICLES ON THE BASIS OF DRUG DELIVERY

Following types of nanoparticles can be used as drug delivery:

- Polymer drug conjugates,
- Liposomes and other lipid based nanomaterials,
- Micelles,
- Polymer microspheres,
- Dendrimers,
- Quantum dots,
- Carbon nanotubes,
- Nanocapsules, and
- Ligand targeted products [13, 16, 26–29].

ASPECTS OF TARGETING

The drug to be delivered for the treatment of cancer will be effective if it reaches the desired tumor tissues without disturbing the blood circulation. Then after reaching the tumor cells it should have ability to kill the tumor cells without harming the healthy tissues. These two strategies are linked with the improving patient health and thereby reducing the toxicity. Anticancer drug can be delivered to the tumor cells by active or passive targeting.

Passive Target Delivery

In passive delivery, nanoparticles are moved through leaky tumor tubes opening into the tumor site by the process of convection or passive diffusion. In passive targeting, drug is assembled at the desired tumor location. The size of nanoparticles and the microenvironment of the tumor cell is advantageous for it. This

technique effectively develops the efficiency and bioavailability of the drugs. Since the tumor vessels are different as compared with normal vessels, so, on the basis of anatomical difference, drug is targeted to the tumor tissues effectively. The gaps in the tumor tissues is about 600–800 nm which is different than the normal tissues. The drug is passed through these gaps and assembles in the tumor tissues. The accumulation of drug at these tissues is possible only if the drug is delivered through nanoparticles and not by free delivery [30–35].

Active Target Delivery

In active delivery, drugs are delivered to a specific region based on recognition of molecules. In such process, a nanoparticle is coupled with a ligand and this ligand interacts with the target cell. In the same way a particular antibody coupled with nanoparticles is used to bind at particular antigenic cell region. For example, folate is bounded with PEGylated particles to interact with folate receptors. The cancer cells express themselves on the surfaces of folate. They have more binding affinity for nanoparticles folate bound proteins as compared with free folate. Then the drug associated with nanoparticles releases to perform action on the targeted cell. This technique can be used for any type of cancer [26, 30–36].

Figure 1 shows the schematic representation of nanoparticle targeting.

- Nanoparticles are concentrated in the tumor interstitium via passive extravasation through the leaky microvasculature shown as gaps in the endothelial layer (light orange). This process has been named the EPR effect. In this case, the efficacy of nanoparticles is largely mediated through the local release of the drug near the cancer cells.
- Targeted nanoparticles similarly concentrate in the tumor interstitium through the EPR effect but once there, nanoparticles are actively taken up by cancer cells after binding to their target antigens on the surface of the cancer cells. In this case the drugs are released largely inside the cancer cells resulting in enhanced efficacy (Figure 1).

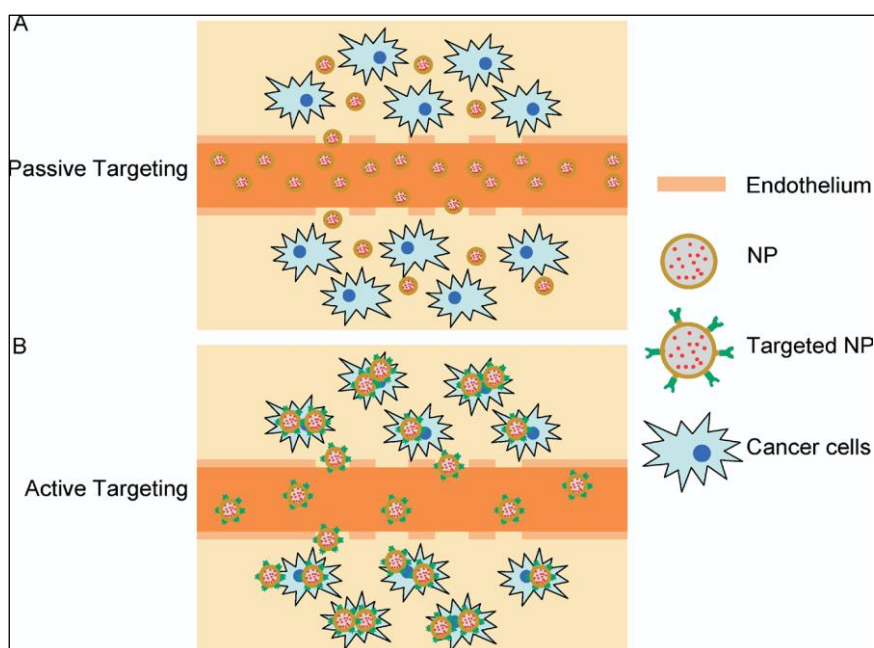


Fig. 1: Schematic Representation of Nanoparticle Targeting [13].

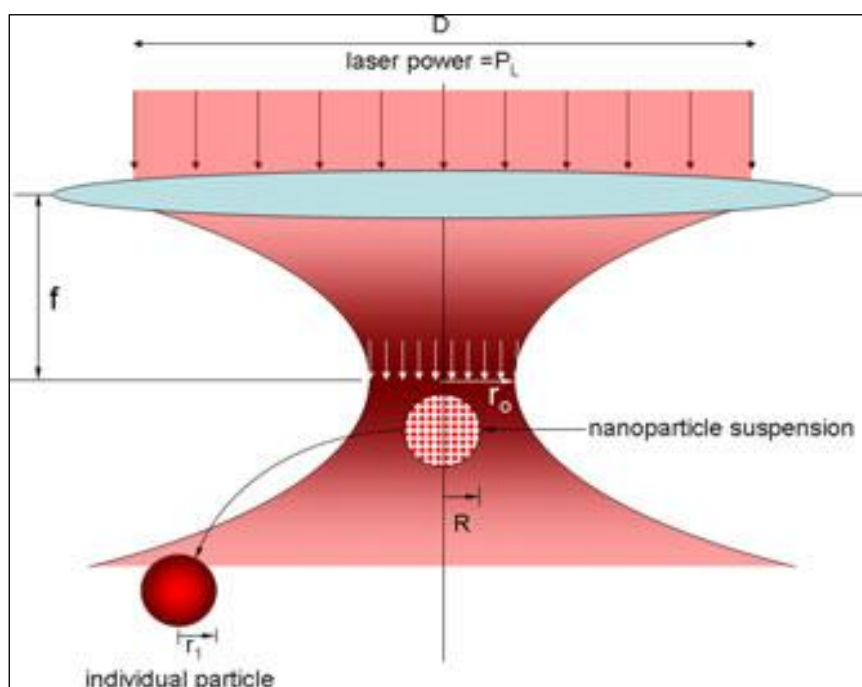


Fig. 2: Schematic Diagram of Laser Particles Interaction where the Nanoparticles are Confined to a Region R .

MODELING LASER HEATING

Another way of use of nanoparticles in cancer treatment is using laser. Nanoparticle is brought in front of laser at a focal distance f from lens. The laser light is penetrated into the fluid and some of its part is absorbed by nanoparticles. In the vicinity of particles, a thermal region is generated where the heat absorbed is dissipated. For heating a continuous wave, laser is used.

Using continuous wave laser, higher temperature range can be achieved depending on the pulse time. The schematic diagram is shown in Figure 2.

The nanoparticle suspension is shown confined to a region R , but in practice, the nanoparticles may be dispersed over a wide zone. r_0 is the focused beam spot size; f , the

focal length; P L, the laser power; and D, the incident beam diameter [6].

It is predicted that the temperature produced can be very large, even greater than the melting temperatures of the particles. Due to this high energy, pulses ($>10^8$ W/pulse) overtime range of nanoseconds to femtoseconds are produced. Absorbed energy of the particles is confined in the near region of the particles (Figure 2) [6, 37, 38].

CONCLUSION

The cancer treatment by the use of nanoparticles is a more effective and efficient way of treatment. Using it, the targeting is very focused and the cancer tissues can be treated very well. It is the great need to develop a mechanism through which healthy tissues cannot be harmed. It can be possible if we reduce the toxicity of nanoparticles. In coming years, it is expected that we may have developed a perfect treatment for cancer without having any of the side effects. The main goal of nanotechnology in application of cancer treatment is to diagnose and treat the cancer at its very early stage without creating any toxicity and without harming the healthy tissues. That time is not far away when we will have such treatment.

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