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Nanotechnology in the treatment of Breast Cancer

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Abstract: Among the most leading causes of mortality for women around the world is breast cancer. Although chemotherapy is the recommended treatment for most cancers, chemotherapy, surgery, and radiation treatment are the three primary therapy methods for the breast cancer treatment. Nanotechnology technologies for cancer therapies has received much interest in recent years. The analysis explores a variety forms of nanoparticles and their implementations for the breast cancer treatment, like liposome, micelles, polymeric nanoparticle, solid lipid nanoparticle, and gold nanoparticle. In recent years, nanotechnology has evolved and been implemented to cancer therapies. Nanotechnology actually plays a key role within selective delivery of drugs used in the treatment of cancers, particularly breast cancer. Nanoparticles could penetrate tumours and monitor the rate of drug release to particular locations, thus enhancing drug therapeutic efficiencies and minimizing common organ or tissue poisoning. In addition, nanoparticle can trigger immune cells towards tumours as well. Therefore, for potential cancer research and treatment, nanoparticles are powerful weapons.

Keywords: Liposomes, Micelles, Polymeric Nanoparticles, Solid Lipid Nanoparticles, Gold Nanoparticles.

INTRODUCTION

Cancer is one of the leading causes of death worldwide and is defined as a disease that begins when cells grow uncontrollably and crowd out normal cells. Cancer can develop anywhere in the body, such as in the lungs, breasts, or liver. The World Health Organization predicted that the burden of cancer will increase to 23.6 million new cases annually by 2030. Thus, cancer treatment has become a prominent issue over the past several decades. For women, breast cancer is one of the most commonly diagnosed cancers globally. In 2018, approximately 266,120 new cases of invasive breast cancer were estimated in women constituting 30% of all cancer cases (878,980 total cases); in addition, 40,920 of these breast cancer cases were estimated to be fatal.

Breast cancer is usually classified on the basis of the type of receptor overexpression present on the cancer cell membrane, including progesterone (PR) and estrogen (ER) hormone receptors and HER2 receptors, with HER2 being a member of the human epidermal growth factor receptor family. Breast cancers that present the overexpression of these receptors are called either PR− , ER− , or HER2- positive, depending on the type of receptor overexpression. Patients that show PR− , ER− , HER2-positive breast cancer cells are said to have triple-positive breast cancer. In addition, triple-negative breast cancer group exists that is composed of breast cancers that are neither PR/ER-positive nor HER2-positive. It has been reported that the primary cause of deaths due to breast cancer is the result of its potential metastasis to distant organs such as the liver, lungs, lymph nodes, bones, and brain.

Currently, surgery (in which whole breast is removed, called a mastectomy, or in which only the tumor and surrounding tissues are removed, called a breast-conserving lumpectomy), chemotherapy (in which drugs are used to kill cancer cells), and radiotherapy (in which high-energy waves are used to kill cancer cells) are the three main cancer treatment strategies.

Among them, chemotherapy is more popularly used for treating most types of cancer. Chemotherapy can kill many cancer cells throughout the body, eradicate microscopic disease at the edges of tumours that may not be seen by a surgeon, and be used in combination with other therapies [1].

Many anticancer drugs such as tamoxifen, paclitaxel, docetaxel, doxorubicin, and methotrexate have been approved for the treatment of breast cancer. However, the poor aqueous solubility and permeability of these drugs have resulted in low bioavailability and decreased treatment efficiency. Thus, the controlled release and tumour-targeted delivery of these anticancer drugs via the use of nanoparticles represent two important strategies to improve therapeutic efficacy and reduce the side effects of cancer treatments.

Nanotechnology has been widely used over the last decades and nanoparticle drug delivery is considered a promising tool for cancer treatments due to the high loading capacity, reduced toxicity, stability, efficacy, specificity, and tolerability of drug-loaded nanoparticles compared to conventional chemotherapy drugs. Anticancer drug loaded nanoparticles can be used to actively or passively deliver drugs to tumours during breast cancer treatments. The advantages to using nanoparticles are not only due to their ability to be created in a range of small sizes but also to their capacity to be made from various substances, such as lipids (e.g. solid lipid nanoparticles, liposomes), polymers (e.g., polymeric nanoparticles), and inorganic materials (e.g. gold nanoparticles). Among the various types of nanoparticles, liposomes, micelles, polymeric nanoparticles, solid lipid nanoparticles, and gold nanoparticles are popularly used in the treatment of breast cancer. Thus, this review focuses on these nanoparticle types and discusses recent advances in the treatment of breast cancer [2].

DISCUSSION

Types of Nanoparticles

To date, nanotechnology has rapidly developed to produce some of the most important cancer treatment strategies. Among the various nanoparticle types, the most popular nanoparticles used in breast cancer treatments are liposomes, micelles, polymeric nanoparticles, solid lipid nanoparticles, and gold nanoparticles (Fig. 1).

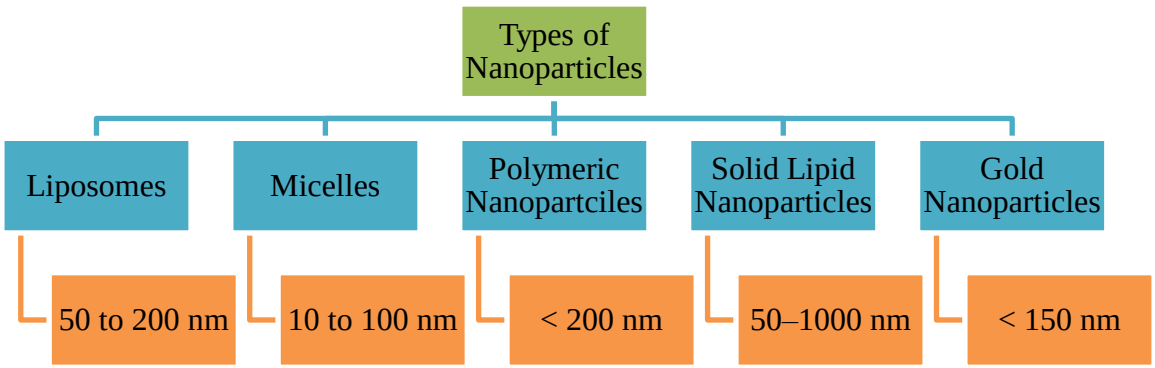

Figure 1. Type and size of different Nanoparticles

Recent advances in nanoparticles for the treatment of breast cancer

Nanoparticle have significant drug delivery efficiency and are commonly used in cancer care. Many other benefits, like high stability, strong encapsulation, as well as the ability to combine both hydrophobic and hydrophilic medications, have been demonstrated by nanomaterials. Few possible consequences have, however, also been seen with nanomaterials. Tiny particle size nanomaterials, for instance, may simply transfer across membrane, penetrate several regions of the body, communicate in an unfavourable way with tissues, and possibly trigger intrinsic damage in several healthy cells [7]. Also, the processing of nanomaterials may be limited by substances. PLGA, for example, is a healthy substance with fewer side effects, but it deteriorates rapidly and does not persist longer enough in tissue for prolonged drug/gene delivery, leading to reduced effectiveness of therapy. The drawback of PLGA could also be resolved by altering the poly-lactic/glycolic acid ratio. For instance, PLGA demonstrate the ability deterioration with the ratios of 50:50 (PLA/PGA) than PLGA with ratios of 65:35 (PLA/PGA) attributable to preferred deterioration of the amount of glycolic acid allocated to higher hydrophilicity. Consequently PLGA 65:35 (PLA/PGA) demonstrates quicker deterioration than PLGA 75:25 (PLA/PGA) and PLGA 75:25 (PLA/PGA) than PLGA 85:15 (PLA/PGA).

The exact amount of the degradation rate therefore is dependent upon the glycolic acid ratio. In adjusting the matrix's hydrophilicity and therefore the degradation rate and release of drugs, the quantity of glycolic acid is an essential factor. nonorganic materials, like carbon nanotube, on the other hand, are robust and can survive for days, month or even year in the body, makes them particularly harmful and restricting their use for repetitive therapies. In addition, over the duration of therapy, some cancerous cells may grow drug resistance, making the drug emitted from the nanoparticles ineffective. Utilizing active targeting ligands to enhance the delivery of anticancer drugs to target cells, the interfaces of nanoparticles have been improved in recent times. Docetaxel liposome, for instance, was formulated with d-alpha-tocopheryl polyethylene glycol 1000 succinate (vitamin E TPGS) and then further conjugated with trastuzumab for cellular absorption to induce cytotoxic effects in SK-BR-3 cells, whilst pharmacokinetics in vivo were also examined in rodents.

Upon 24 hours of incubation by SK-BR-3 cells, the IC50 value of the marketing preparations of docetaxels, TPGS liposome and trastuzumab-conjugated TPGS liposome were 20.23 ± 1.95, 3.74 ± 0.98, and 0.08 ± 0.4 μg/mL, respectively. Furthermore, in the pharmacokinetic analysis, the half-life of trastuzumab-conjugated TPGS liposome was tenfold higher when compared with docetaxel only. In another research, PLA-TPGS, which was eventually combined with trastuzumab for the treatment of HER2-positive breast cancer, has been used in the processing of emtansine nanomaterials as a polymer. In breast cancer cells, the toxicity of emtansine nanoparticle-trastuzumab was greater than that of emtansine and trastuzumab alone [3].

In vivo, comparison to the non-targetting community upon treatment in MDA-MB-453 xenograftbearing rats, the nanomaterials displayed less harmful effects and prevented cancer growth by 88 percent. In order to boost internalisation and cytotoxicity in BT-474, SK-BR-3, and MCF-7 breast cancer cells, alternative techniques like adsorption, bioconjugation, and charged adsorption have been implemented to change the surface of docetaxel-PLGA nanoparticles with Herceptin (HCT). In BT-474, SK-BR-3, and MCF-7 breast cancer cells, the cellular absorption of HCT-bioconjugated nanoparticles was 5.0, 4.4, and 4.6-fold greater than

those of the nanomaterials, respectively. Comparison to other preparations, the cytotoxic activity of HCT-bioconjugated DTX-nanoparticles in BT-474, SK-BR-3, and MCF-7 breast cancer cells was greater. In addition, tumor-targeting gold nanorod (AuNR)-photosensitizer analogues were created to boost effective tumor-targeting stabilities utilizing glutathione-sensitive linkages for successful photodynamic (PDT)/photothermal (PTT) treatments, and in vitro cytotoxicity and cellular localization were also explored in MCF-7 breast cancer cells. Better stabilization and bio - compatibility were demonstrated in the AuNR-photosensitizer analogues. Moreover, AuNR-photosensitizer conjugate absorption in vitro was shown by more than 99 percent of MCF-7 breast cancer cells.

CONCLUSION

Presently, nanoparticle studies for breast cancer care have grown rapidly and have concentrated mainly on the use of targeting ligands to reach optimal tumour accumulation. HER2 is among the most prominent cell surface receptors in breast cancer cells, and this receptor is being used to counter conventional anticancer drugs like paclitaxel, docetaxel, and doxorubicin effectively. Treatment performance is enhanced through using targeting ligands in the synthesis of nanoparticles and toxicity is prevented in healthy cells comparison to nanoparticles lacking targeting ligands. Nanoparticles, however, are an useful strategy for the potential breast cancer treatment as well as other tumours.

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