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RECENT TRENDS ON SOLID LIPID NANOPARTICLE AS TARGETED POLYMER BASED DRUG DELIVERY SYSTEM IN THE TREATMENT AND MANAGEMENT OF BREAST CANCER

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ABSTRACT:
Solid Lipid Nanoparticles (SLNs) have emerged as a promising nanocarrier system in the field of oncology, particularly in the targeted treatment of breast cancer. SLNs, composed of biocompatible and biodegradable lipids, offer significant advantages over traditional drug delivery systems, including enhanced drug stability, controlled release profiles, and reduced systemic toxicity. Recent advancements in SLN formulations have enabled the encapsulation of a wide range of chemotherapeutic agents, immunotherapeutic agents, and nucleic acids, thereby improving the bioavailability and therapeutic efficacy of these compounds in breast cancer therapy. The ability of SLNs to target tumor cells selectively through surface modification with ligands such as antibodies, peptides, and folate, facilitates site-specific drug delivery, enhancing treatment efficacy while minimizing off-target effects. Additionally, SLNs can exploit the Enhanced Permeability and Retention (EPR) effect, further contributing to their tumor-targeting potential. Recent studies have demonstrated the ability of SLNs to overcome common challenges in breast cancer treatment, such as drug resistance, poor solubility of hydrophobic drugs, and the need for sustained drug release. Moreover, the integration of SLNs with multimodal therapy, including combination chemotherapy, immunotherapy, and gene therapy, represents a promising strategy to address the complex and heterogeneous nature of breast cancer. Despite the promising preclinical and clinical data, challenges related to large-scale production, stability, and regulatory approval of SLN-based formulations remain. This review highlights the recent progress in SLN-based drug delivery systems for breast cancer treatment, discusses their current limitations, and outlines future directions for improving their clinical translation
Keywords: **Solid lipid nanoparticle, Breast cancer, Drug delivery, Drug resistance, Apoptosis**

INTRODUCTION

Breast cancer is one of the most common and significant cancers globally, with an increasing incidence across both developed and developing countries. It arises when abnormal cells in the breast tissue begin to grow uncontrollably, forming a mass or tumor. While breast cancer primarily affects women, men can also develop the disease, though at much lower rates. The World Health Organization (WHO) reported in 2020 that approximately 2.3 million women were diagnosed with breast cancer, and 685,000 women died from it globally, making it the leading cause of cancer-related deaths in women. Risk factors for breast cancer include age, family history, genetic mutations (such as mutations in the BRCA1 and BRCA2 genes), hormonal factors (e.g., early menstruation and late menopause), and lifestyle factors like obesity, alcohol consumption, and lack of physical activity. The disease can be classified into different types, with invasive ductal carcinoma (IDC) being the most common. Early detection through screening, particularly mammography, plays a critical role in improving survival outcomes, with treatments ranging from surgery and chemotherapy to hormone therapy and targeted therapies, depending on the type and stage of cancer. Advances in molecular biology and personalized medicine have significantly enhanced treatment options, although challenges remain in addressing disparities in outcomes, especially in lower-income settings [1]

Solid Lipid Nanoparticles (SLNs) are emerging as a promising nanotechnology-based approach in the treatment of breast cancer due to their ability to improve the delivery and efficacy of chemotherapeutic agents while minimizing systemic side effects. SLNs, composed of biocompatible solid lipids, offer several advantages in breast cancer therapy, including enhanced solubility of hydrophobic drugs, controlled drug release, and targeted delivery to tumor cells. By encapsulating drugs like doxorubicin**,** paclitaxel**,** and docetaxel, SLNs can improve the bioavailability and therapeutic effectiveness of these chemotherapeutics, which are often limited by poor solubility and toxicity. Moreover, the surface of SLNs can be functionalized with targeting ligands (such as antibodies or peptides) to enhance specificity for breast cancer cells, reducing damage to healthy tissues and minimizing side effects. Additionally, SLNs provide sustained release profiles, allowing for prolonged drug action and reduced frequency of administration. They can also be designed to bypass biological barriers, such as the blood-brain barrier, which is particularly beneficial for treating metastatic breast cancer that has spread to the brain. Despite challenges in drug loading capacity and potential instability issues, ongoing research into optimizing SLN formulations holds great promise for improving breast cancer treatment outcomes. Their ability to combine therapeutic and targeted delivery mechanisms positions SLNs as a potential cornerstone in the future of personalized breast cancer therapy.[2]

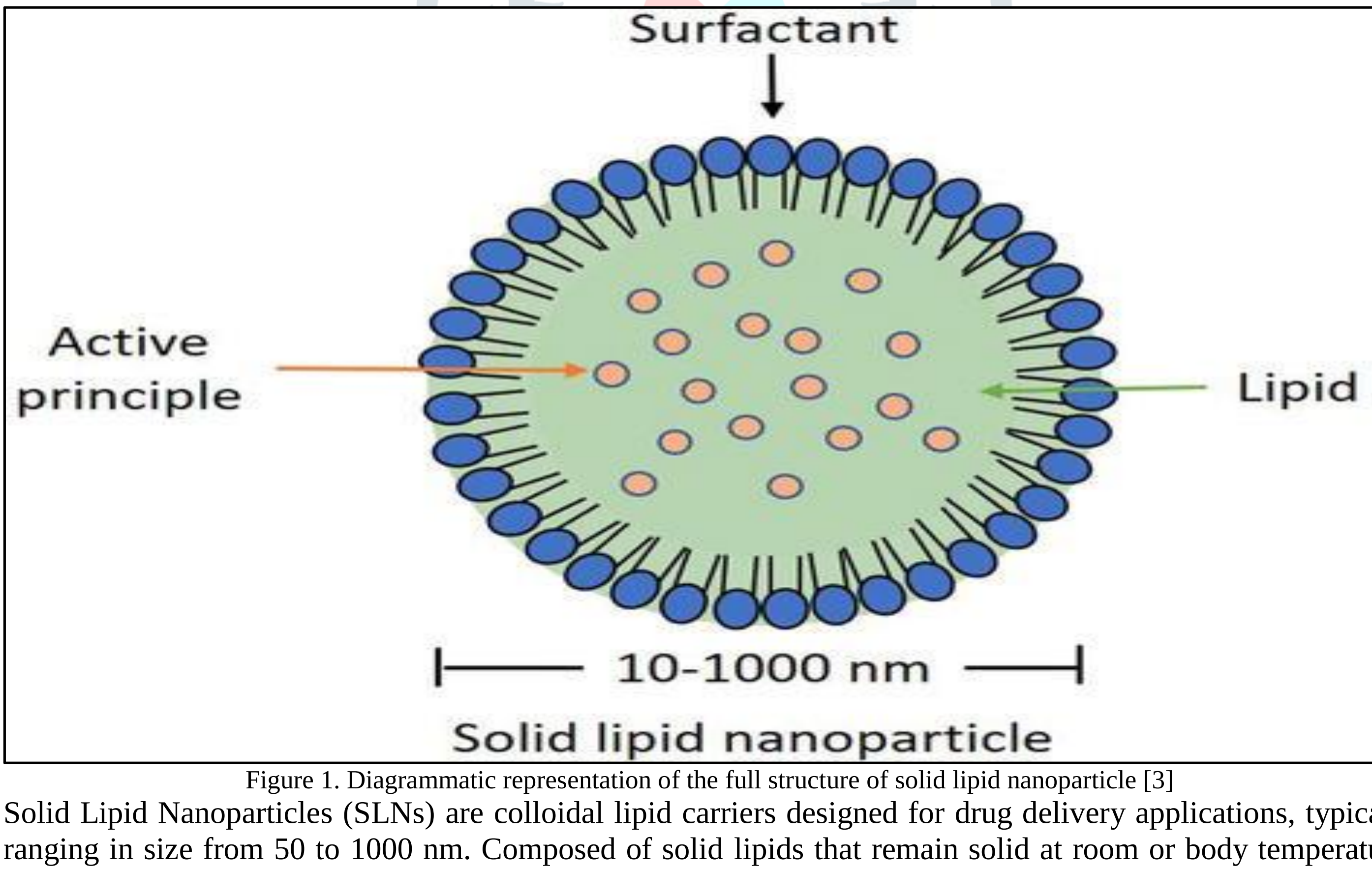

Figure 1. Diagrammatic representation of the full structure of solid lipid nanoparticle [3]

Solid Lipid Nanoparticles (SLNs) are colloidal lipid carriers designed for drug delivery applications, typically ranging in size from 50 to 1000 nm. Composed of solid lipids that remain solid at room or body temperature, SLNs offer several advantages, including biocompatibility, biodegradability, and the ability to protect encapsulated drugs from degradation. They are particularly useful for delivering poorly soluble, lipophilic drugs, and can also be adapted to encapsulate hydrophilic substances, making them versatile carriers. SLNs provide controlled release properties, improving drug bioavailability and reducing side effects. They are typically prepared using techniques such as high-pressure homogenization, solvent evaporation, or microemulsion methods, all of which enable the formation of stable nanoparticle dispersions. Despite these advantages, SLNs face challenges related to limited drug loading capacity, particularly for hydrophilic compounds, and stability issues such as particle growth or fusion during storage. Additionally, SLNs may exhibit polydispersity, which can affect their performance. Their applications span a wide range of fields, including pharmaceutical drug delivery, gene therapy, and cosmetics, where they enhance skin penetration of active ingredients and provide sustained release. In pharmaceutical applications, SLNs are also being explored for targeted drug delivery, where surface modification with specific ligands can direct the nanoparticles to targeted tissues or cells. Overall, while SLNs offer significant potential, ongoing research is aimed at addressing their limitations and optimizing their use in various therapeutic and cosmetic applications[4]

The application of Solid Lipid Nanoparticles (SLNs) in targeted drug delivery for breast cancer therapy has garnered significant attention in recent years due to their potential to overcome the limitations of conventional drug delivery systems. The review aims to explore the latest advancements in the development of SLNs for the targeted delivery of anticancer agents specifically to breast cancer cells, thereby improving therapeutic efficacy and minimizing systemic side effects. SLNs are well-suited for this purpose due to their unique properties, such as biocompatibility, biodegradability, ability to encapsulate both hydrophilic and hydrophobic drugs, and controlled drug release profiles. Recent research has focused on modifying the surface of SLNs with targeting ligands (e.g., antibodies, peptides, or aptamers) to enhance selective accumulation at tumor sites, leveraging the enhanced permeability and retention (EPR) effect and specific receptor-mediated endocytosis. Furthermore, SLNs can be designed to co-encapsulate chemotherapeutic drugs with other therapeutic agents like genes, siRNA, or immunomodulatory substances to achieve synergistic effects, such as enhanced apoptosis, overcoming drug resistance, or modulating the tumor microenvironment. Advances in the formulation techniques of SLNs, including surface modification with polyethylene glycol (PEG) for increased circulation time, have also been explored. The review will examine recent studies that highlight these innovations, providing insights into how SLNs can address the critical challenges of breast cancer therapy, such as targeting heterogenous tumors, reducing toxicity, and overcoming multidrug resistance (MDR). Moreover, clinical trials and in vivo studies on SLN-based formulations will be discussed to assess their translational potential for breast cancer therapy.[5]

Table No.1 A table summarizing the composition and structure of Solid Lipid Nanoparticles (SLNs), including references for more in-depth understanding.

Component	**Description**	**Role**	**Examples**
Solid Lipid Core	Core made from solid lipids, solid at body temperature (37°C).	Acts as the matrix to encapsulate the drug or active ingredient. Provides stability and controlled release.	Triglycerides (e.g., tripalmitin, tristearin) - Fatty acids (e.g., stearic acid, oleic acid) - Waxes (e.g., cetyl palmitate, beeswax)
Surfactant/ Emulsifiers	Compounds that stabilize SLNs by reducing surface tension.	Prevent particle aggregation and stabilize the dispersion in water.	Polysorbate 80 -Poloxamers -Lecithin, cetyltrimethylammonium
Active Pharmaceutical Ingredients (APIs)	Drug substances or active compounds encapsulated within the lipid matrix or adsorbed on the surface	Provide the therapeutic effect; can be hydrophobic or hydrophilic	Hydrophobic drugs (e.g., curcumin, paclitaxel) - Hydrophilic drugs (e.g., insulin, peptides)
Water/Aqueous Phase	Water-based solvent used to prepare the SLNs dispersion.	Serves as a dispersing medium, ensuring proper formulation and particle formation.	Water or aqueous buffer solutions used for dispersion and emulsification

Particle Size	SLNs generally range between 50-1000 nm.	Determines the bioavailability, drug release, and cellular uptak SLNs generally range between 50-1000 nm.	- SLNs typically fall within this size range for efficient drug delivery and controlled release.
Lipid Crystalline Matrix	Arrangement of lipids within the core, can be crystalline, amorphous, or a mix.	Affects the stability and drug release profile. Crystallinity impacts the encapsulation efficiency and release.	- Type I (amorphous) - Type II (crystalline) - Type III (mixed)
Surface	A layer of surfactants covering the lipid core to prevent aggregation.	Stabilizes SLNs, reduces surface tension, and aids dispersion in biological systems	Surfactant layer (Polysorbate 80, lecithin)
Drug Encapsulation	The method by which drugs are either incorporated in the lipid matrix or adhered to the surface.	Encapsulates the therapeutic agent for sustained release or targeted action.	Drugs are either encapsulated within the lipid core (hydrophobic) or adhere to the surface (hydrophilic

Advantages of SLNs over Other Nanocarriers

Solid Lipid Nanoparticles (SLNs) offer several advantages over other nanocarriers such as liposomes, polymeric nanoparticles, and dendrimers. One of the main benefits is their superior biocompatibility and safety, as they are composed of lipids that are generally regarded as safe (GRAS), reducing the risk of toxicity compared to synthetic polymers or dendrimers. SLNs also provide controlled and sustained drug release due to their solid lipid core, which minimizes drug leakage and enhances therapeutic efficacy while reducing side effects, making them ideal for long-term drug delivery[6]. Unlike liposomes, which can suffer from instability and drug leakage, SLNs maintain structural integrity, ensuring greater stability**,** Additionally, SLNs are prepared using aqueous-based methods, avoiding the need for toxic organic solvents often required by other nanocarriers, which makes them more environmentally friendly**.** They also significantly improve the bioavailability of poorly water-soluble drugs, offering a solution for lipophilic drugs that are challenging to deliver via conventional methods [7]. Moreover, SLNs protect labile drugs, such as proteins and nucleic acids, from degradation, ensuring drug stability during storage and delivery. Their ability to be targeted to specific tissues or cells by functionalizing the lipid surface with targeting ligands also gives them an edge over other carriers in precision medicine applications Furthermore, SLNs are easier to scale up for large-scale production, making them suitable for commercial pharmaceutical applications[8]. These features make SLNs a versatile and promising choice for drug delivery systems.

Mechanisms of SLNs in Breast Cancer Therapy

Active targeted nanoparticles, a novel nanoscale approach has been developing for the localization and cellular internalization in the tumor sites. Growth factors, hormones, receptor expression, protein up regulations are involved in signaling pathways for tumor development and metastasis have been identified for the site-specific targeting, internalization and localization of liposomes in the tumors therapeutic, diagnostic and the ranostic approaches. Active targeted nanoparticles are the surface-modified or functionalized passive targeted nanoparticles are successful in tumor targeting and site-specific release of the chemotherapeutics[9]. Antibodies, peptides, nucleic acid aptamers, carbohydrates and some molecules are the ligands used to conjugate the nanoparticles for the active targeting of tumors. Important targets for the induction of apoptosis or inhibition of anti-apoptosis, angiogenesis, cell-cycle arrest and signal transduction in the breast cancer treatment have been summarized in Figure 2. In vitro and in vivo studies which have concentrated in active targeting of breast cancer

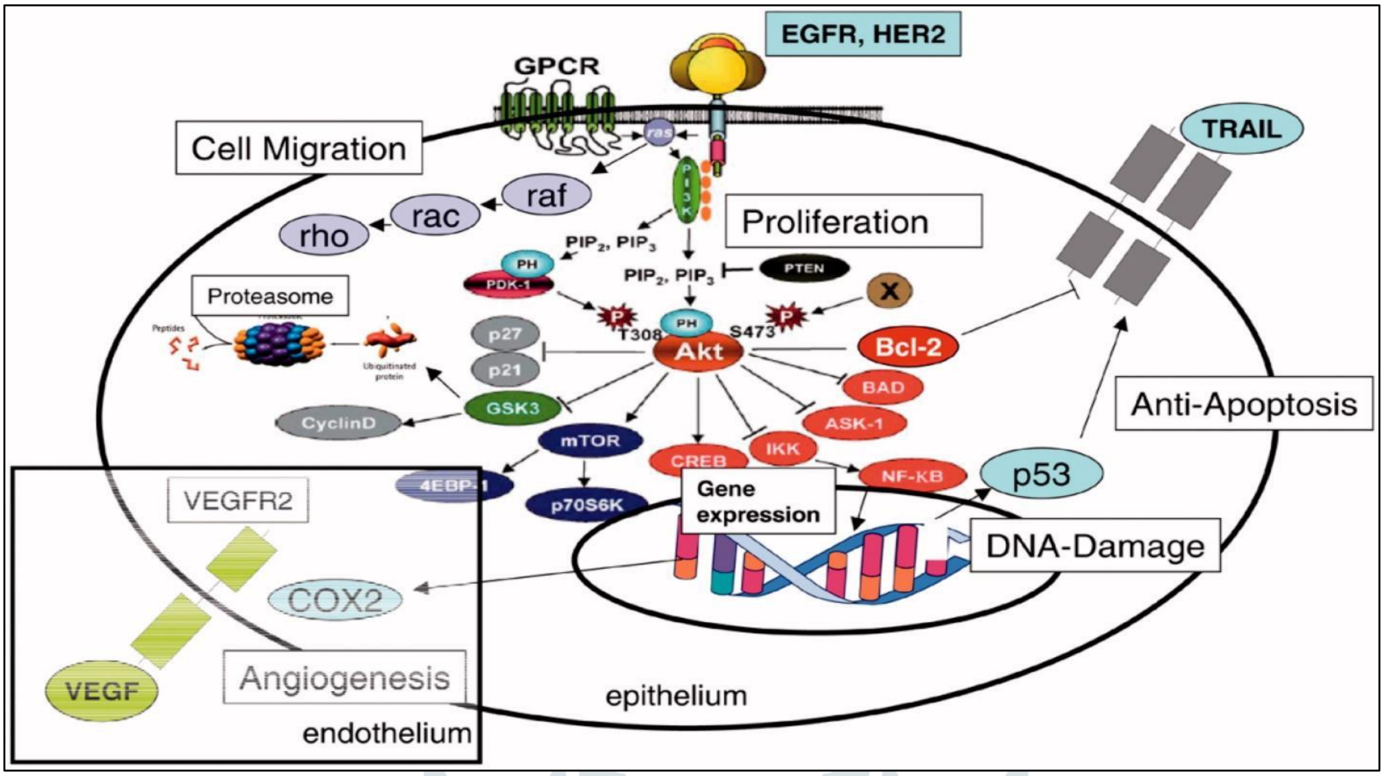

Figure 2. Summary of targets for the induction of apoptosis or inhibition of anti-apoptosis, angiogenesis, cell-cycle arrest and signal transduction in thebreast cancer treatment. EGFR, epidermal growth factor receptor; GPCR, G-protein-coupled receptors; HER, human epidermal growth factor receptor;IKK, inhibitor of NF-B kinase; mTOR, mammalian target of rapamycin; NF-B, nuclear factor-B; TRAIL, tumor necrosis factor-related apoptosisinducing ligand; VEGF, vascular endothelial growth factor; VEGFR, vascular endothelial growth factor receptor[10]

Targeted Drug Delivery to Cancer Cells

Passive Delivery

In passive delivery, the properties of SLNs, such as size, composition lipid, and surface characteristics, play a crucial role. One of the main characteristics of tumors is the stimulation of angiogenesis to promote increased nutrients and oxygen. However, blood vessel formation results in a defective architecture with fenestrations (from 200 to 1200 nm)[11] This pathology is the enhanced permeability and retention effect (EPR). Therefore, SLNs accumulate in the tumor through passive diffusion via the EPR effect, penetrating through the fenestrations and remaining there due to poor lymphatic drainage nanoparticles, with sizes ranging from 50 to 200 nm, which can reach passively the tumor site. Surface modification of SLNs with hydrophilic polymers such as polyethylene glycol (PEG) can enhance their circulation time by reducing opsonization and clearance by the reticuloendothelial system (RES), thus promoting passive accumulation at the target site. PEGylation is the most important surface modification of nanoparticles. PEG increases time circulation, and it has been reported that it enhances particle permeation in tumors[12].

Active Delivery

There have been several studies on active delivery; generally, nanoparticles are functionalized by adjusting the composition of SLNs; they can be readily functionalized with various targeting methods to facilitate active delivery against specific cell types of interest. This modification aims to enhance the targeting efficiency of nanoparticles and reduce the side effects [13] Active delivery involves modifying the surface of nanoparticles with several ligands that are overexpressed on the tumor cells, such as small molecules, peptides, antibodies, polysaccharides, hormones, and nucleic acids. These molecules are recognized by cell receptors or transporters[14] The specific interaction between the surface ligands of nanoparticles and their receptor expression on the target cells could facilitate the internalization process through endocytosis. It has been reported that nanoparticles modified with folate for active targeting showed enhanced cellular uptake by endocytosis[15].

Triggered Release

Triggered release mechanisms play a crucial role in drug delivery systems. These drug release mechanisms depend on various stimuli in the tumor microenvironment or external agents to control the release(process) Some of the critical stimuli and their associated responses include pH; it is known that tumors often have a lower pH compared to healthy tissues, and SLNs can be designed to respond to this acidic pH to release therapeutic agents. Other stimuli are magnetic field, ultrasonic, and temperature. Magnetic solid lipid nanoparticles use an external magnetic field to control their location, thus avoiding the disadvantages of systemic administration. Once magnetic drug carriers accumulate within a tumor, an externally applied alternating magnetic field (AMF) can increase the drug release and temperature[16] In the case of ultrasound, waves can trigger the release of drugs from nanoparticles in the tumor area without affecting healthy tissue. It has been reported that exposure to ultrasound produces a reversible permeability on cell membranes and increases the drug into the tumor[17] Hyperthermia is a common strategy used in cancer therapy, where tumors are heated to temperatures slightly higher than normal body temperature and nanoparticles release their therapeutic agents in tumors[18]

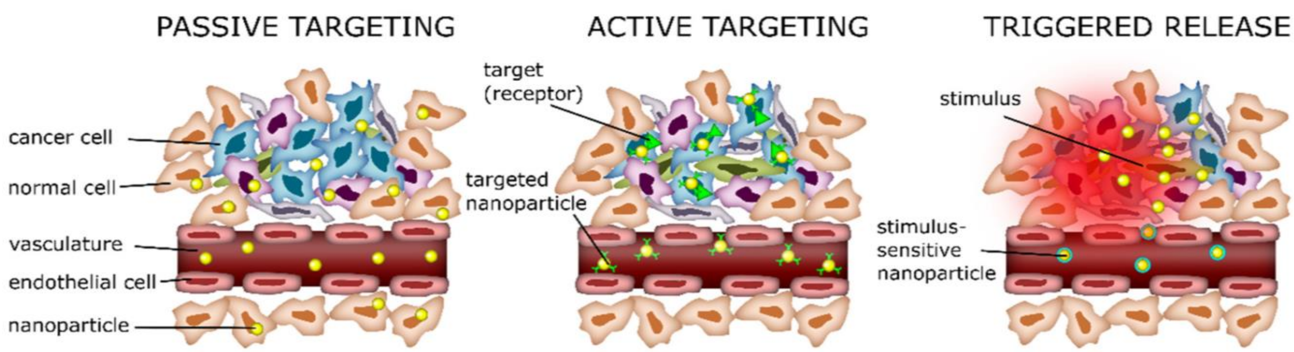

Figure 3. Schematic representation of drug targeting via passive (EPR effect), active, and triggered release[19]

Role of Ligand-Loaded SLNs in Breast Cancer Therapy

Most side effects of antitumor drugs are caused by damage to normal cells because of the low specificity of the drugs. To overcome this limitation, various methods have been developed to increase the specificity of a drug by conjugating it with a tumor-specific antibody or ligand. SLNs conjugated with hormone receptor-specific antibodies enhance the targeting potential for breast cancer cells. Compared to SLN treatment alone, some in vitro and in vivo studies have shown enhanced antitumor effects of cationic SLNs linked to CAB51 and HER2 binding antibodies. The linkage between SLNs and CAB51 can be achieved via streptavidin-biotin interactions. Incubation of the SLN-streptavidin complex with the biotinylated antibody mixture forms the SLN-streptavidin-antibody. As the zeta potential is closely related to physical stability, these methods are affected by changes in the zeta potential of the nanoparticle surface. According to studies on the treatment of HER2-overexpressing cells with normal SLNs compared to antibody-conjugated SLNs, a greater reduction in cancer cell viability was observed with antibody-conjugated sentinel node treatment. In addition, treatment with the antibody-SLN complex showed much lower cancer cell viability than CAB51 treatment alone at the same dose. These synergistic effects of SLNs linked to the HR antibody proved promising for specific antitumor effects.
However, HR-targeting treatments are not effective for HR-negative breast cancer. Unlike the HR-positive subtype, TNBC can be targeted via death receptor-5 (DR5) because TNBC cells have a higher proportion of DR5 on the cell surface than normal cells. Recent studies have shown that DR5 antibody-conjugated SNPs have high cytotoxicity and decreased off-target effects in TNBC cells, both in vitro and in vivo. These effects seem to result from the synergistic activity between SLNs and DR5 antibodies, which leads to site-specific delivery. In addition to antibody-conjugated SLNs, SLNs have been modified with cancer cell-targeting ligands such as folic acid (FA) to increase drug specificity. FA-conjugated SLNs combined with antitumor drugs, such as letrozole (LTZ), enhance drug efficacy by inducing cancer-specific apoptosis in breast cancer. These results suggest that ligand-loaded SLNs are a promising approach to target-specific breast cancer treatment. With this concept, more patients are expected to overcome these diseases without experiencing side effects[20]

SLNs for Chemotherapy in Breast Cancer

Paclitaxel (PTX) is an effective chemotherapy drug that is at the forefront of treatment for various types of tumors such as ovarian, breast, and lung cancers. The use of this drug is associated with side effects such as nephrotoxicity and neurotoxicity. By examining the effects of the SLN formulation of this drug, reduction in renal toxicity, long-term antitumor effects, increased drug absorption, and decreased breast tumor size were observed in mice

Methotrexate, as an antimetabolite drug, is effective for the treatment of breast, leukemia,

lymphoma, lungs, osteosarcoma, and bladder cancers. In an in vivo study, intravenous administrationof methotrexate-loaded SLNs led to the accumulation of the drug within breast cancer tissue comparedwith the free drug. Additionally, a considerable enhance in the life span of the treated mice withmethotrexate-loaded SLNs was observed [21].

Doxorubicin, a natural factor, is commonly used as an anti-cancer compound. In addition

to causing resistance in the cancer cells, its administration induces cardiac toxicity. It has been

reported that doxorubicin-loaded SLNs induce high cytotoxicity and a high absorption capacity in doxorubicin-resistant human breast cancer cell[22].

Hormonal compounds such as tamoxifen have been loaded into SLNs for drug-resistant breast

cancer cells. The cytotoxic and aggressive activity of tamoxifen-SLN was higher than the free-tamoxifen in the drug-resistant breast cancer cells[23]

Finally, considering the benefits, properties, and the high efficiency of SLNs in increasing the

therapeutic effects and reducing the side effects of chemotherapy drugs, it is suggested that other

anti-breast cancer drugs such as epirubicin, emodin, docetaxel, and capecitabine should be formulatedin SLNs and their efficacy should be studied in vivo.

Table 2. Surface modified targeted SLNs for breast cancer therapy

Target	Drug	Cancer	Main outcomes	Reference
Folic acid	Letrozole	Breast cancer	FA-SLNs-LTZ exhibited significantly higher cytotoxicity against MCF-7 cancer cells compared to SLNs-LTZ with minimal systemic side effects	[24]
Carbohydrate	Doxorubicin	Breast cancer	For targeted delivery of DOX, which demonstrated higher cellular uptake, cytotoxicity, and nuclear localization against A549 cells, indicating an efficient formulation for cancer therapy	[25]
	Methotrexate	Breast cancer	Improved internalization by cells, and increased toxicity against breast cancer cells, along with improved bioavailability, and tumor targeting efficiency, leading to a significant reduction in tumor volume	[21]
Transferrin	Tamoxifen citrate	Breast cancer	Enhance the active targeting of tamoxifen citrate in breast cancer therapy, demonstrating increased cytotoxicity and therapeutic response in human breast cancer MCF-7 cells compared to pure tamoxifen	[26]

			citrate solution	
Antibody	Streptavidinbiotin	Breast cancer	Fabricated nanocarriers showed increased internalization, and a synergistic effect on cell viability in HER2 overexpressing BT-474 breast cancer cells compared to non-targeted SLNs	[27]
peptide	paclitaxel/lonidamine	Breast Cancer	targeting system inhibited the Warburg effect and promoted mitochondrial binding of pro-apoptotic Bcl-2 proteins strategy enhanced the therapeutic index of both drugs	[28]
Hyaluronic acid	Ibuprofen and Paclitaxel	Breast cancer	-Improvement in cellular uptake and induction of apoptosis. -Significantly higher inhibition of the growth of the MDA-MB-231 cells.	[29]

Table 3. List of nanochemodrugs which are under clinical research study in Breast Cancer

Trial id	stage	Study title	drug	doses	status	Sponsor	Outcome
NCT03799679	Phase 4	Albumin-Bound Paclitaxel Followed by Epirubicin in Combination With Cyclophosphamide in Triple Negative Breast Cancer	Nab-Paclitaxel Epirubicin Cyclophosphamide	125mg (IV) 90mg(IV)	Completed	Fudan University	breast pathological complete response (bpCR, ypT0/is) rate, objective response rate (ORR), the proportio

				600 mg(IV)			n of patients requiring breast-conserving surgery, and safety
NCT03671044	Phase 3	A Study to Evaluate the Efficacy and Safety of Nanosomal Docetaxel Lipid Suspension in Triple Negative Breast Cancer Patients	Docetaxel	75 mg (IV)	Recruiting	Jina Pharmaceuticals Inc.	Patient will be dosed with drug until disease progression and/or unacceptable toxicity
NCT00110695	Phase 2	Therapy With Abraxane and 5-Fluorouracil, Epirubicin, Cyclophosphamide (FEC) for Patients With Breast Cancer	5-Fluorouracil	500mg	Completed	NSABP Foundation Inc	determine pathologic complete response rate in the breast for patients with locally advanced breast cancer
NCT00662129	Phase 2	Paclitaxel Albumin-Stabilized Nanoparticle Formulation, Gemcitabine, and Bevacizumab in Treating Patients With Metastatic Breast Cancer	Paclitaxel Gemcitabine	300 mg 1000 mg	Completed	Alliance for Clinical Trials in Oncology	maximum tolerated dose of nab-paclitaxel is 300 mg/m^2 in combination with gemcitabine 1000 mg/m^2 on days 1, 8 every 21 days.

NCT00654836	Phase 2	Carboplatin, Paclitaxel, and Bevacizumab in Treating Patients With Locally Recurrent or Metastatic Breast Can cer	Bevacizumab Carboplatin	15 mg	Completed	Loyola University	works in treating patients with locally recurrent or metastatic breast cancer
NCT00331630	Phase 1	Abraxane and Lapatinib in Treating Patients With Stage I, Stage II, or Stage III Breast Cancer	lapatinib ditosylate paclitaxel albumin-stabilized nan oparticle	1 tab/day oral for 21 days	Completed	Northwestern University	Abraxane and lapatinib in HER2-positive breast cancer, evaluating efficacy, safety, and response rates.

Challenges and Limitations of SLNs in Breast Cancer Therapy

Solid lipid nanoparticles (SLNs) offer promising potential for drug delivery in breast cancer therapy, but their application comes with several challenges and limitations. One primary challenge is the difficulty in achieving consistent drug loading and release profiles, which can affect the therapeutic efficacy. Variability in the size and surface characteristics of SLNs may lead to inconsistent drug distribution and hinder their ability to target tumor cells effectively. Additionally, while SLNs are designed to improve the bioavailability of poorly soluble drugs, their stability in biological environments remains a concern, as they can undergo aggregation or degradation over time. There are also challenges in scaling up the production of SLNs, as the manufacturing process needs to maintain high quality and reproducibility for clinical use. Moreover, SLNs can induce immune responses or toxicity, particularly when they accumulate in non-target tissues, leading to side effects. Finally, the limited ability to cross certain biological barriers, such as the blood-brain barrier in cases of brain metastasis, reduces the applicability of SLNs in treating all forms of breast cancer.

Future Perspectives

Recent advances in the application of Solid Lipid Nanoparticles (SLNs) for targeted drug delivery in breast cancer therapy are paving the way for more effective and personalized treatments. Researchers are increasingly focusing on functionalizing SLNs with specific ligands, antibodies, or peptides that target tumor cells, ensuring precise drug delivery while minimizing side effects. SLNs are also being optimized for combination therapies, where they carry multiple drugs that target different cancer pathways, potentially overcoming drug resistance. Advances in drug loading and controlled release mechanisms are improving the therapeutic outcomes by enhancing drug concentration at the tumor site while reducing systemic exposure. Additionally, new biocompatible and biodegradable lipid materials are being developed to reduce toxicity and improve safety profiles. Efforts are also being made to enhance SLNs' ability to cross biological barriers, such as the blood-brain barrier, to treat metastatic breast cancer. Furthermore, the integration of SLNs with personalized medicine approaches is allowing for more tailored and effective therapies based on the genetic makeup of individual patients. As manufacturing processes are refined and regulatory hurdles are addressed, SLNs hold great promise for revolutionizing breast cancer therapy with improved precision, safety, and efficacy.

Conclusion

As addressed in this review, large quantum of work has been carried out and overwhelming evidences are available. The basic concept of lipid nanocarriers as a well-tolerated carrier is confirmed and well documented. Lipids used in the development of liposomes, SLNs, NLCs and LPN are non-toxic, biocompatible and biodegradable with low or no immunogenicity. The lipids are able to form a nanostructure and it has been widely investigated as a nanocarrier for tumor-targeted drug delivery. Lipid-based nanomedicine has shown substantial therapeutic potential to treat a variety of diseases for both research and clinical applications. Physiochemical properties of drug and lipids can be optimized to customize the geometrical parameters, such as particle size, shape and encapsulation efficiency, and drug release behavior pattern. Characterization of the formulation is also a critical attribute, which controls the product quality, stability and release kinetics. These lipid nanocarriers exhibit passive drug delivery exhibits enhanced therapeutic effect. The presence of reactive functional groups in lipids facilitates for conjugation of proteins and some other targeting agents for tumor-targeted drug delivery. These lipid nanocarriers and their derivatives are conjugated with hydrophobic moieties and tumor-targeting ligands are found to exhibit a prolonged circulation time in blood and diminish uptake by the reticuloendothelial system (RES) due to their smaller size. Moreover, these lipid nanocarriers are able to target various portions of the tumor using targeting ligands and reduce the problems associated with multi-drug resistance. It is evident that lipid nanocarriers have tremendous potential as tumor-targeted drug-delivery for cancer therapy and they are fortunate as almost 40% of the new drug entities are lipophilic. In recent years, theranostic nanocarriers shown promissory results in the emerging field of personalized medicine, as they detect as well as monitor individual patient's cancer at an early stage and deliver anticancer agents thereby enhanced therapeutic efficacy. Practically, non-invasive monitoring of the theranostic carriers enables clinicians have to rapidly fix on whether the regimen is effective in an individual patient or not. For these reasons, cancer theranostic functioned nanoparticles presents a novel promising strategy in breast cancer treatment. In this perspective, lipid-based nanocarriers conjugated/or encapsulated with targeting ligands and imaging agents would bring a great breakthrough by simultaneous diagnosis of tumors, targeted drug delivery with less toxicity and monitoring of treatment.

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