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RESEARCH PAPER

Systematic Review of Drug Nanocarriers in Breast Cancer Treatment: Focusing on Liposomes and Polymeric Nanoparticles

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ABSTRACT

Breast cancer remains one of the most prevalent and challenging cancers to treat, necessitating advancements in therapeutic strategies. This systematic review aims to evaluate the efficacy of drug nanocarriers, with a specific focus on liposomes and polymeric nanoparticles, in the treatment of breast cancer. Utilizing a comprehensive search strategy across multiple databases, we identified and analyzed relevant studies that investigate the use of these nanocarriers in breast cancer therapy. Our findings indicate that both liposomes and polymeric nanoparticles offer significant advantages in targeted drug delivery, enhanced therapeutic efficacy, and reduced systemic toxicity compared to conventional treatment methods. Liposomes, due to their biocompatibility and ability to encapsulate both hydrophilic and hydrophobic drugs, have shown promising results in clinical trials. Polymeric nanoparticles, with their customizable properties and sustained drug release capabilities, also demonstrate substantial potential in breast cancer treatment. However, each type of nanocarrier presents unique challenges in terms of stability, scalability, and regulatory approval. This review highlights the key advancements, comparative efficacy, and future prospects of liposomes and polymeric nanoparticles, underscoring their critical role in advancing breast cancer therapeutics.

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INTRODUCTION

Breast cancer is one of the leading causes of cancer-related mortality amongst girls worldwide [1].

According to (WHO), the worldwide mortality charge for breast most cancers in 2022 changed into about 670,000 deaths. This determine displays the ongoing project that breast cancer poses international and underscores the importance of endured research and development in remedy techniques [2].

despite advancements in early detection and remedy, it stays a big clinical undertaking because of its heterogeneous nature and the capability for metastasis. modern-day healing strategies, including surgical operation, chemotherapy, radiation, and hormonal therapy, frequently face limitations together with non-precise focused on, systemic toxicity, and drug resistance[3].

Those challenges spotlight the urgent want for more powerful and targeted remedy options which in latest years, drug nanocarriers have emerged as a promising answer to enhance the delivery and efficacy of anticancer treatment options [4]. Nanocarriers, along with liposomes and polymeric nanoparticles, offer numerous benefits over traditional drug transport systems. those consist of progressed solubility, superior permeability and retention (EPR) impact, and the ability to supply pills particularly to tumor cells whilst sparing wholesome tissues [5]. Also thay are designed enabling preferential accumulation in tumor tissues, thereby mitigate the destructive results on wholesome cells. with the aid of leveraging these properties, nanocarriers have the ability to overcome the various boundaries related to traditional cancer treatments [6].

This systematic review assess the cutting-edge of research on the use of drug nanocarriers, mainly liposomes and polymeric nanoparticles, within the remedy of breast cancer.

Our evaluation seeks to spotlight the novelty and ability effect of liposomes and polymeric nanoparticles in breast cancer therapy. via this evaluate, we purpose to contribute to the ongoing efforts to improve breast most cancers remedy outcomes and pave the manner for the combination of nanocarrier-based drug delivery systems in clinical trials.

METHODOLOGY

The method for the systematic assessment on drug nanocarriers in breast cancer remedy involved an in depth seek strategy across databases like PubMed, Google pupil and Scopus, using specific key phrases. The evaluate blanketed peer-reviewed articles published from 2000 to April 2024, focusing on the efficacy, mechanisms and shape of liposomes and polymeric nanoparticles. information has been extracted on observe information, nanocarrier types, and key findings. The analysis became qualitative, evaluating the two nanocarrier types and assessing their medical effects. This methodical approach aimed to offer a thorough evaluation of the contemporary proof on nanocarriers in breast most cancers therapy.

OVERVIEW OF DRUG NANOCARRIERS

Drug delivery has been transformed by nanocarriers, especially in the context of cancer treatment. By delivering therapeutic substances straight to the site of disease, these nanoscale vehicles aim to maximise the drug's effectiveness and reduce any systemic side effects. A wide variety of materials, each with specific characteristics and uses in cancer treatment, are included in the definition of a nanocarrier, including liposomes, polymeric nanoparticles, dendrimers, solid lipid nanoparticles, and inorganic nanoparticles [7]. numerous varieties of nanocarriers, such as Liposomes are spherical vesicles made of phospholipid bilayers that can hold both hydrophilic and hydrophobic medications within. They are among the first nanocarriers for the treatment of cancer to receive clinical approval. Liposomes are spherical vesicles made of a bilayer of phospholipids that can be used to encapsulate a wide variety of medicinal substances [8]. Because of their amphiphilic properties, medications that are hydrophobic can be accommodated within the lipid bilayer while those that are hydrophilic can be found within their watery core [9]. Because of their distinct structural makeup, liposomes are incredibly adaptable and among the first nanocarriers to be approved for use in clinical settings to treat cancer. Liposomes' biocompatibility and capacity to improve the pharmacokinetics and pharmacodynamics of encapsulated medications are responsible for their clinical usefulness in oncology [10]. Targeted medication delivery can be facilitated by adding targeting ligands, such as peptides or antibodies, to the liposome surface. This allows the liposomes to be guided towards particular cancer cell markers

[11]. By increasing the drug's accumulation at the tumour site, this focused method aims to minimise off-target effects and maximise therapeutic efficacy. Moreover, liposomes can be modified to respond differently to different stimuli—like pH, temperature, or enzymes—that are present in the tumour microenvironment [12].

The medicine is delivered in a regulated manner at the tumour site thanks to these stimuli-responsive liposomes, which stay stable during circulation but release their payload in reaction to particular triggers [13]. The treatment of certain malignancies, including ovarian, breast, and Kaposi's sarcoma, has significantly improved with the discovery of liposomal formulations like Doxil® (liposomal doxorubicin) [14].

These formulations have been demonstrated to enhance patients' quality of life while lowering the cardiotoxicity linked to free doxorubicin. In conclusion, liposomes represent the state-of-the-art in oncology drug delivery systems based on nanocarrier technology [15]. Their ongoing development and application in clinical settings promise to revolutionise cancer therapy by increasing the effectiveness, patient-centeredness, and personalisation of therapies [16]. Polymeric nanoparticles can encapsulate a diverse range of therapeutic agents, including hydrophilic and hydrophobic drugs. This versatility allows for tailored drug loading. Surface modifications enable targeted drug delivery [17]. Ligands or antibodies can be conjugated to nanoparticles, facilitating active tumor targeting. Additionally, passive targeting occurs through the EPR effect, where nanoparticles accumulate in leaky tumor vasculature. Polymeric nanoparticles provide sustained drug release kinetics [18]. This controlled release ensures prolonged exposure of tumor cells to therapeutic agents, potentially improving treatment outcomes. Polymeric nanoparticles achieve higher drug concentrations within tumor tissues [19]. This augments cellular uptake and intracellular retention of encapsulated drugs. By selectively delivering drugs to tumor sites, polymeric nanoparticles minimize exposure to healthy tissues, mitigating adverse effects [20]. Polymeric nanoparticles can co-deliver drugs that inhibit resistance pathways, addressing multidrug resistance commonly encountered in breast cancer. Thay represent a versatile and effective platform for the targeted delivery of chemotherapeutic agents in breast cancer therapy [21]. Their structural diversity and functionalizability make them an invaluable tool in the ongoing fight against this complex disease. polymeric nanoparticles represent a paradigm shift in breast cancer therapeutics. Their ability to enhance drug delivery precision, reduce toxicity, and overcome resistance underscores their potential to revolutionize breast cancer treatment [22].

Dendrimers are rather branched, tree-like macromolecules that offer considerable versatility in drug delivery due to their monodisperse, symmetrical structure and inner cavities appropriate for drug encapsulation [23]. Their particular, stepwise synthesis lets in for great floor functionalization, enabling the conjugation of a couple of healing marketers and concentrated on moieties [24]. In oncology, dendrimers facilitate focused most cancers therapy by using binding to most cancers mobile receptors, making sure green drug transport, and minimizing systemic facet outcomes [25]. They guard encapsulated capsules from untimely degradation and may respond to tumor-specific stimuli for controlled release [26]. Additionally, dendrimers can cross biological boundaries like the blood-mind barrier, enhancing drug shipping to the CNS [27]. Their structural precision and multifunctionality cause them to promising for subsequent-technology, customized therapeutics [28]. strong Lipid Nanoparticles (SLNs) combine the benefits of lipid-based companies and polymeric nanoparticles, imparting a strong matrix for drug encapsulation [29]. Composed of solid lipids like triglycerides, SLNs defend healing agents from degradation and provide sustained drug launch, improving healing efficacy and reducing dosing frequency [30].

Their biocompatibility and versatility in administration routes (oral, parenteral, topical, ocular) cause them to suitable for numerous cures. surface changes can enhance circulate time and targeting. Produced through scalable strategies like high-stress homogenization, SLNs enhance bioavailability of poorly soluble drugs and patient compliance, representing a promising strengthen in drug transport and personalized remedy [31]. Inorganic nanoparticles, crafted from materials like gold, silica, or iron oxide, are flexible gear in cancer remedy and analysis due to their unique optical, magnetic, and structural properties. Gold nanoparticles (AuNPs) are biocompatible and

used for imaging and targeted drug delivery, with their photothermal effect permitting localized most cancers mobile destruction [32]. Silica nanoparticles offer excessive drug loading capacity and might release drugs in response to tumor-precise stimuli, additionally helping in imaging. Iron oxide nanoparticles decorate MRI evaluation and can be guided to tumors magnetically [33], with capability for magnetic hyperthermia to set off tumor mobile death. these nanoparticles aid a theranostic technique, combining treatment and actual-time tracking. but, challenges in toxicity, biodistribution, and synthesis must be addressed for scientific use [34]. Nanocarriers exploit the EPR impact to build up in tumor tissues, that have leaky vasculature and negative lymphatic drainage. This permits for sustained drug release at once at the tumor web site, enhancing drug concentration even as lowering systemic toxicity [35].

Nanocarriers can be functionalized with ligands to bind to unique receptors overexpressed on cancer cells, like HER2/neu in breast most cancers, ensuring unique drug transport and minimizing impact on healthful cells. Nanocarriers can be designed to launch pills in reaction to particular stimuli in the tumor microenvironment, which includes pH or enzymes, bearing in mind a sustained healing impact [36]. By way of turning in drugs without delay to the tumor website online, nanocarriers minimize publicity of wholesome tissues to toxic chemotherapeutic marketers, leading to fewer facet results [37]. Nanocarriers beautify the solubility of hydrophobic drugs, increasing their bioavailability and healing capability. Nanocarriers can convey multiple types of healing agents, along with tablets, genes, and imaging dealers, taking into consideration aggregate remedy and theranostics [38]. Nanocarriers can bypass drug resistance mechanisms by using facilitating intracellular drug transport or co-turning in tablets with marketers that inhibit resistance pathways.

In essence, nanocarriers offer an extra centered, effective, and patient-friendly method to most cancers treatment, and are expected to grow to be an essential part of personalised medicine [39].

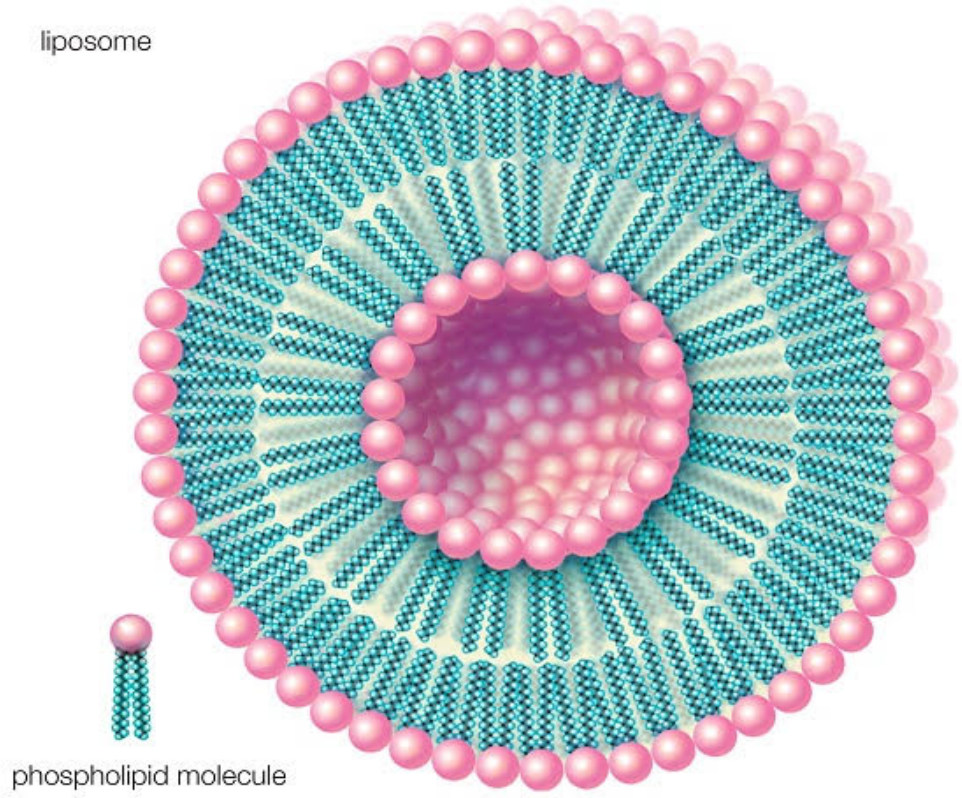

Fig. 1. Liposome Nanocarier structure

Liposomes in Breast Cancer Treatment

the context of breast maximum cancers therapy, liposomes offer severa benefits, which includes the ability to encapsulate each hydrophilic and hydrophobic capsules, controlled launch kinetics, and centered shipping [40].

This twin capability complements the ability of liposomal drug formulations. managed launch kinetics allow sustained and localized drug shipping, lowering the frequency of dosing and minimizing systemic issue outcomes. centered transport is executed by way of the usage of floor amendment with ligands or antibodies that apprehend cancer-specific markers, improving drug accumulation at the tumor net page. Stimuli-responsive liposomes, represent a complex advancement in the targeted treatment of breast most cancers. those specialized nanocarriers are engineered to launch their drug payload in response to particular triggers in the tumor microenvironment, in conjunction with versions in pH, temperature, or enzyme pastime [41]. This focused shipping system is designed to growth the eye of the drug at the internet site online of the tumor, thereby enhancing the therapeutic effect whilst simultaneously lowering the negative element effects commonly related to traditional chemotherapy. This specificity reduces off-target effects and will increase healing efficacy, making liposomes an effective tool in personalized breast cancer treatment strategies [42].

Structure and composition of liposomes

The phospholipid bilayer is the crucial detail of liposomal architecture, offering a biomimetic barrier that encapsulates healing agents for centered delivery in breast most cancers treatment. The bilayer's composition is meticulously engineered to reflect cellular membranes, which includes a numerous array of phospholipids and cholesterol, conferring the liposome with vital traits for drug transport (liposoms structure is shown in Fig. 1) [43]. Phospholipid choice, desire of phospholipids like phosphatidylcholine and phosphatidylethanolamine (PE) is critical. computer contributes to bilayer fluidity and is identified for its biocompatibility, while PE affords a poor charge at physiological pH, which can be exploited for floor changes. About cholesterol Integration, cholesterol performs a pivotal function in modulating the bilayer's homes. It intercalates a few of the phospholipid molecules, improving the pressure and decreasing the permeability of the. bilayer. this is especially useful in preventing premature drug leakage and stabilizing the liposome against the shear forces encountered in systemic movement[44]. The dynamic nature of the bilayer allows for the incorporation of polyethylene glycol (PEG) and different polymers to create a 'stealth' impact, reducing recognition and clearance by the reticuloendothelial machine (RES). This prolongs the flow time of liposomes, increasing the likelihood of tumor localization via the EPR impact [45].

surface Functionalization shows bilayer's outer surface can be functionalized with targeting ligands, inclusive of antibodies or peptides, that bind to overexpressed receptors on breast cancer cells. This active targeting complements the specificity of the liposome, directing the encapsulated pills to the tumor web site with excessive precision [46]. In precis, the phospholipid bilayer's composition and characteristics are finely tuned to optimize the transport of anticancer drugs. Its structural integrity, mixed with the potential to go through floor adjustments, makes liposomes a flexible and effective nanocarrier within the realm of breast cancer therapeutics. the ongoing research and improvement on this area retain to refine liposomal formulations, aiming to maximize their therapeutic potential whilst minimizing detrimental outcomes [47].

Mechanisms of liposomes in Breast Cancer

Liposomes can encapsulate hydrophilic drugs within their aqueous middle and hydrophobic capsules inside the lipid bilayer. This twin encapsulation functionality permits for the shipping of a huge variety of therapeutic marketers. The encapsulation protects tablets from degradation, complements their solubility, and allows controlled release [48]. Liposomal encapsulation shields healthful tissues from direct exposure to cytotoxic tablets. In breast cancer, this translates to reduced cardiotoxic consequences, minimizing the hazard of heart damage related to anthracyclines. floor change of liposomes with targeting ligands (e.g., antibodies) enables active transport to breast most cancers cells. those ligands apprehend overexpressed receptors (e.g., HER2/neu) on cancer cells, ensuring selective accumulation of liposomes at the tumor website [49]. Floor change of liposomes is an essential method to beautify their specificity and efficacy

in breast cancer remedy. via attaching ligands including antibodies, peptides, or small molecules to the liposome surface, researchers can take advantage of receptor-mediated endocytosis to obtain targeted drug shipping. these ligands are selected based on their affinity for receptors which can be overexpressed on breast most cancers cells. as an instance, HER2 (human epidermal growth issue receptor 2) is normally overexpressed in a subset of breast cancers, making it a really perfect target for ligand attachment. Antibodies like trastuzumab (Herceptin®) can be conjugated to the liposome surface, permitting the liposome to bind mainly to HER2-fantastic cancer cells. This focused technique no longer most effective enhances drug accumulation at the tumor web page however also reduces off-target consequences, leading to improved therapeutic consequences and decreased systemic toxicity [50]. To further improve the pharmacokinetics of liposomal drug formulations, polyethylene glycol (PEG) is frequently conjugated to the surface of liposomes, growing PEGylated liposomes. PEG is a hydrophilic polymer that gives a steric barrier across the liposome, preventing popularity and uptake with the aid of the mononuclear phagocyte device (MPS), which could in any other case hastily clean the liposomes from move. This "stealth" feature prolongs the circulate time of liposomes, bearing in mind multiplied accumulation at the tumor website through the improved permeability and retention (EPR) effect. The EPR impact arises from the leaky vasculature and negative lymphatic drainage typically located in tumors, which allows the preferential accumulation of nanoparticles like liposomes [51]. The clinical implications of surface-changed liposomes are profound. for example, PEGylated liposomal doxorubicin (Doxil®) has proven considerable enhancements in patient consequences through reducing cardiotoxicity and growing the healing index as compared to traditional doxorubicin. furthermore, the focused transport done thru floor amendment enhances the precision of breast most cancers treatments, permitting better doses of chemotherapeutics to be brought without delay to most cancers cells even as sparing healthful tissues. This focused technique is specifically useful in treating competitive and metastatic breast most cancers paperwork, where precision medicine is vital for effective control [52]. pH-Responsive Liposomes are designed to come to be risky and release their contents while encountering the acidic conditions frequently discovered in tumor tissues, as a consequence making sure that the drug is released where it is most wished [53]. Temperature-Responsive Liposomes, leverage the slightly better temperature of tumor tissues to cause drug launch, doubtlessly in conjunction with hyperthermia remedies that further localize and enhance the healing motion [54]. Enzyme-Responsive Liposomes via responding to enzymes overexpressed in tumor tissues, these liposomes make sure that the drug is launched inside the presence of precise biological markers associated with cancer cells [55]. Liposomes revolutionize breast most cancers treatment by using turning in capsules at once to tumors, improving efficacy and lowering facet results. They utilize surface changes for precise targeting of most cancers cells, increasing drug attention on the tumor site. PEGylated liposomes evade immune detection, prolonging their presence within the bloodstream and enhancing drug transport via the EPR effect. responsive to the tumor environment, they launch drugs in response to particular stimuli, optimizing therapeutic motion. those improvements symbolize a primary stride in customized oncology, promising progressed affected person results with reduced toxicity [56].

Advantages and limitations

In extra to advantages of liposomes these nanocarrier have many limitations like that

biological obstacles that regardless of their focused on capabilities, liposomes have to overcome numerous organic obstacles to reach tumor cells, which can now and again restrict their effectiveness [57]. Variable EPR impact makes the improved Permeability and Retention (EPR) impact can be inconsistent amongst patients, affecting the accumulation of liposomes within the tumor tissue [58]. Immunogenicity and Clearance show whilst PEGylation enables steer clear of immune detection, some liposomes may also still be recognized and cleared through the body's immune device, lowering their stream time [59]. Layout of liposomes is complicated and calls for cautious consideration of their composition, length, floor price, and ligand attachment, that may complicate manufacturing and scalability [60]. Cost the production of liposomes, especially those with specialised concentrated on talents, can be high-priced, which may affect their

accessibility and good sized use in scientific settings [61]. In end, liposomes represent a widespread advancement in breast most cancers remedy, imparting focused, controlled, and green drug transport. however, their scientific software isn not without demanding situations. Ongoing studies and technological upgrades intention to conquer those boundaries, improving the efficacy and applicability of liposomal formulations in the remedy of breast most cancers [62].

Clinical Trials studies

Josimar O Eloy et al [63], developed a liposome-based drug delivery system combining paclitaxel and rapamycin, which showed promising results in treating breast cancer. The liposomes effectively encapsulated the drugs, had suitable particle properties, and improved the drugs' bioavailability. They were stable, released drugs gradually, and were more effective against breast cancer cells compared to the drugs alone. Result of In Vivo and In vitro test showed, The liposomes were more cytotoxic to the 4T1 breast cancer cell line than the free drugs, indicating a higher efficacy in killing cancer cells. Additionally, the drugs within the liposomes acted synergistically, enhancing their therapeutic effect when co-loaded. Also in animal models, specifically 4T1-tumor-bearing mice, the co-loaded liposome formulation controlled tumor growth more effectively than the solutions of the drugs alone. This suggests that the liposome formulation has a significant potential for improving breast cancer treatment outcomes in a clinical setting.

Gopal Venkatesh Shavi et al [64], focused on developing PEGylated liposomes containing anastrozole for long-term breast cancer treatment. Key findings include, encapsulation efficiencies ranged from 65.12 ± 1.05% to 69.85 ± 3.2%. Mean particle size distribution was 101.1 ± 5.9 nm for AL-07 and 120.2 ± 2.8 nm for AL-09 liposomes. Zeta potentials were −43.7 ± 4.7 mV for AL-07 and −62.9 ± 3.5 mV for AL-09. The release kinetics followed the Higuchi-matrix model with a Korsemeyer–Peppas n-value between 0.5 and 1.0. indicating anomalous transport. PEGylated liposomes significantly inhibited tumor growth in BT-549 and MCF-7 cell lines ($p < 0.05$). Pharmacokinetic studies in Wistar rats showed a 3.33-fold and 20.28-fold increase in AUC (0–∞) for conventional and PEGylated liposomes, respectively, compared to the pure drug ($p < 0.001$). These results suggest that PEGylated liposomes are promising for effective and sustained breast cancer treatment.

Sumeet Dagar et al [65], studied on VIP grafted sterically stabilized liposomes (SSL) for targeted imaging of breast cancer revealed the following key points, Vasoactive intestinal peptide (VIP), which binds to receptors overexpressed in breast cancer, was used to target the SSL to the cancer cells. The SSL encapsulated a radionuclide, Tc99m-HMPAO, without altering its size or encapsulation ability due to the presence of VIP. VIP did not change the pharmacokinetic profile of the SSL. Both VIP-grafted and non-grafted SSL accumulated significantly more in breast cancer tissue compared to normal breast tissue, indicating passive targeting. SSL with VIP showed significantly higher accumulation in breast cancer than SSL without VIP.

The ratio was significantly higher for Tc99m-HMPAO encapsulating VIP-SSL compared to non-VIP SSL, suggesting active targeting to breast cancer. These results demonstrate that Tc99m-HMPAO encapsulating VIP-SSL can be effectively used for targeted imaging of breast cancer.

Ankitkumar S Jain et al [66], investigated Tamoxifen (TMX)-coated liposomes loaded with Doxorubicin (DOX) for targeted breast cancer treatment. Key findings include

TMX-DOX liposomes had a mean size of 188.8 ± 2.2 nm and a positive charge of +47 mV. They released 25.9% of DOX at pH 7.4 over 48 hours, compared to 64.5% at pH 5.5. TMX-DOX liposomes were more toxic to estrogen receptor-positive (ER +ve) MCF-7 cells than other forms of DOX ($P < 0.05$). No difference in toxicity was observed between TMX-DOX liposomes and DOX liposomes in estrogen receptor-negative (ER –ve) MDA-MB-231 cells. TMX-DOX liposomes showed greater cellular and nuclear uptake of DOX in MCF-7 cells. In vivo, TMX-DOX liposomes significantly inhibited tumor growth in mice compared to DOX alone ($p < 0.05$), indicating targeted efficacy.

Jie Meng et al [67], introduced a PEGylated liposome co-encapsulating Resveratrol (Res) and paclitaxel (PTX) for treating multidrug-resistant tumors. The liposome had an average size of 50 nm and encapsulation efficiencies (above 50%). It showed strong cytotoxicity against drug-resistant MCF-7/Adr tumor cells and improved drug bioavailability and retention in tumors. In mice, the liposome significantly inhibited tumor growth

($p < 0.01$) without increasing toxicity, indicating its potential to enhance treatment of drug-resistant tumors.

Liang Zhang et al [68], developed a phosphatidylserine (PS)-targeted liposomal nanoprobe for imaging breast cancer, which involved: Nanoprobe Composition, conjugation of a human monoclonal antibody, PGN635, targeting PS to polyethylene glycol-coated liposomes containing superparamagnetic iron oxide nanoparticles (SPIO) and near-infrared dye, DiR. Characterization of the nanoprobe PGN-L-IO/DiR was characterized and confirmed for its binding specificity and internalization into PS-exposed vascular endothelial cells (ECs). MRI and optical imaging of mice with breast MDA-MB231 tumors showed a significant reduction in signal intensity and T2 values at 24 hours' post-injection, indicating effective tumor targeting. About Pharmacokinetics and Biodistribution, PGN-L-IO/DiR showed reduced accumulation in the liver and spleen, with specific localization to the tumor, demonstrating its potential as a platform for targeted delivery of imaging agents or anticancer drugs.

Hang Xing et al [69], developed AS1411 aptamer-functionalized liposomes containing doxorubicin, targeting nucleolin on MCF-7 breast cancer cells. These liposomes showed increased cellular uptake and cytotoxicity in vitro and enhanced antitumor efficacy in vivo, demonstrating their potential for highly specific drug delivery in cancer therapy.

Qi Zhang et al [70], developed PFV-Lip-PTX, a novel liposome modified with hydrophobic cell-penetrating peptides (CPPs) and loaded with paclitaxel for breast cancer treatment. Key findings include, PFV-Lip-PTX had a diameter of about 120 nm and exhibited a negative charge. Paclitaxel was released from the liposomes in a controlled and sustained manner. PFV-Lip-PTX showed higher internalization efficiency in MCF-7 cells compared to non-modified liposomes. The PFV modification improved the cytotoxicity of paclitaxel. In vivo, PFV-Lip-PTX led to efficient targeting and accumulation in MCF-7 xenograft tumors and improved antitumor efficacy. PFV-Lip-PTX demonstrated low systemic toxicity, with minimal changes in body weight and no significant histological changes in major organs. These results suggest that PFV-Lip-PTX is a promising approach for targeted and effective breast cancer treatment.

Colby S Shemesh et al [71], developed and evaluated a thermosensitive liposomal delivery system using indocyanine green (ICG) for photodynamic therapy (PDT) of breast cancer, triggered by near-infrared (NIR) irradiation. Significant reduction in cell viability was observed following NIR irradiation of liposomal ICG (LPICG). NIR irradiation of LPICG led to a temperature rise, correlating with increased concentrations of ICG. LPICG showed a significant increase in systemic distribution and circulation half-life. Enhanced accumulation of LPICG within the tumor region was demonstrated via NIR fluorescence imaging. Mice treated with LPICG followed by NIR irradiation exhibited significantly reduced tumor growth compared to those treated with free ICG (FRICG), saline, and irradiation alone. The study concludes that LPICG provides targeted biodistribution and superior anti-tumor efficacy, with potential for NIR image-guided delivery and biodistribution monitoring in a human triple-negative breast cancer xenograft model.

Shinya Shimoda et al [72], developed Hybrid liposomes (HL-n) for targeting breast cancer, which showed promising results both in vitro and in vivo. The HL-n, with a hydrodynamic diameter of 100nm, increased fusion with and accumulation in MDA-MB-453 breast tumor cells. They induced apoptosis by reducing mitochondrial membrane potential and activating caspases. In a xenograft mouse model, HL-n significantly reduced tumor volume and induced apoptosis without the use of additional drugs, demonstrating their potential as a standalone therapeutic agent for breast cancer treatment.

Mohammad A Altamimi et al [73], developed luteolin-loaded transdermal elastic liposomes (OLEL1) for breast cancer treatment. OLEL1 showed a high drug entrapment of 92%, a size of 202 nm, and a permeation rate of ~3270 μg/cm² over 24 hours, which was significantly higher than conventional liposomes and drug solution. The permeation flux of OLEL1 was 136.3 μg/h/cm², and it demonstrated superior anticancer activity in vitro against MCF-7 cell lines. These results suggest that OLEL1 could be an effective method for transdermal delivery of luteolin to control breast cancer.

Riwang Li et al [74], developed a thermosensitive liposomal hydrogel (CSSH/Cur-Lip gel) for the delivery of curcumin to prevent breast cancer recurrence. The hydrogel, which encapsulated curcumin within liposomes coated with thiolated

chitosan, had cumulative release ratio of 31.57 ± 1.34% at 12 hours. It demonstrated good cytocompatibility and significant cytotoxicity against MCF-7 cells, reducing breast cancer recurrence in vivo after tumor resection. The CSSH/Cur-Lip gel's injectable and in situ-formable properties make it a promising carrier for sustained drug delivery and tissue regeneration post-tumor resection.

Baolan Tang et al [75], focused on developing liposome ligands modified with branched biotins to target SMVT receptors, which are overexpressed in breast cancer cells. Four types of modified liposomes—Bio-Lip, Bio-Bio-Lip, tri-Bio-Lip, and Tetra-Bio-Lip—along with an unmodified version (Lip), were prepared to evaluate their targeting capabilities against breast cancer. Tri-Bio-Lip demonstrated the most potent anti-proliferative effect on breast cancer cells when loaded with the chemotherapy drug paclitaxel. In cellular uptake studies, tri-Bio-Lip showed the highest internalization ability in both mouse (4T1) and human (MCF-7) breast cancer cells, with uptake rates significantly higher than the other liposomes. In vivo studies using 4T1 tumor-bearing mice confirmed that tri-Bio-Lip had the greatest enrichment at tumor sites, aligning with the in vitro results. The research concluded that increasing the density of targeting molecules on liposomes significantly improves their ability to target breast cancer. The study suggests that the branching structure and spatial arrangement of biotin residues are crucial for binding to SMVT receptors. As a result, tri-Bio-Lip is highlighted as a promising candidate for a targeted drug delivery system in breast cancer treatment.

Rammohan Devulapally et al [76], investigated a therapeutic approach for triple negative breast cancer (TNBC) by targeting two microRNAs, miR-21, which induces antiapoptosis, and miR-10b, which induces metastasis. The treatment involved antisense-miR-21-PS and antisense-miR-10b-PS delivered via polymer nanoparticles (NPs) made from PLGA-b-PEG. Substantial reduction in tumor growth was observed in mice treated with the targeted NPs at a low dose of 0.15 mg/kg. There was a 40% reduction in tumor growth compared to mice treated with scramble peptide conjugated NPs. The results suggest that multitarget antagonization of miRNAs with targeted polymer NPs could be an effective strategy for treating metastatic cancer, offering a new potential therapeutic option forTNBC.

POLYMERIC NANOPARTICLES IN BREAST CANCER TREATMENT

The biodegradable polymers used to make polymeric nanoparticles, such as poly (lactic-co-glycolic acid) (PLGA), allow for the controlled release of a payload over time. Biodegradable polymers like poly (lactic-co-glycolic acid) can be used to create polymeric nanoparticles, which are a major breakthrough in the field of medication delivery [77].

With a regulated release profile that is precisely tailored to the pharmacological requirements of the treatment, these nanoparticles are painstakingly designed to contain a variety of therapeutic compounds. Because PLGA is biocompatible and biodegradable, it is a great material to use to create safe, metabolised nanoparticles that can be eliminated from the body [78].

By varying the ratio of its monomers, lactic acid and glycolic acid, the degradation fee of PLGA may be altered, enabling a customisable release timetable ranging fromdays to weeks or maybe months [79].

This temporal manipulate over drug release is essential for maintaining therapeutic drug stages inside the systemic flow, thereby enhancing treatment efficacy and patient compliance. furthermore, the surface residences of polymeric nanoparticles may be changed to acquire targeted shipping. through conjugating focused on moieties including antibodies, peptides, or small molecules that understand particular markers on cancer cells, these nanoparticles may be directed to accumulate preferentially at the tumor site [80]. This centered technique minimizes the exposure of healthy tissues to cytotoxic drugs, decreasing damaging facet consequences and improving the therapeutic index. Polymeric nanoparticles additionally provide the power to co-deliver more than one tablets, enabling combination remedy inside a single nanocarrier [81].

This approach is in particular useful in overcoming multidrug resistance, a commonplace task in cancer remedy. via delivering a synergistic aggregate of drugs, polymeric nanoparticles can correctly target distinct pathways involved in tumor increase and survival [17]. The capability of polymeric nanoparticles extends beyond chemotherapy. they're being explored for the delivery of genetic fabric, which include DNA and

RNA, opening new avenues for gene remedy and customized medicine. additionally, their utility in vaccine shipping has won significant attention, especially with the appearance of nanoparticle-based vaccines for infectious illnesses [82]. In conclusion, polymeric nanoparticles, particularly the ones made from PLGA, offer a versatile and robust platform for the shipping of healing marketers. Their potential to offer managed release, targeted shipping, and co-shipping of multiple pills positions them on the slicing edge of drug shipping studies. As the sector progresses, these nanocarriers hold the promise of notably improving the landscape of treatment for numerous sicknesses, inclusive of most cancers.

Structure and types of polymeric nanoparticles

Polymeric nanoparticles are generally composed of biocompatible and biodegradable substances such as polylactic acid (PLA), polyglycolic acid (PGA), and their copolymers. The structure of PNPs may be tailored to gain desired properties like length, floor fee, and drug release profiles (Polymers structure is shown in Fig. 2) [83]. They normally have a core-shell structure in which the healing agent is encapsulated in the center, and the shell is frequently modified with concentrated on ligands to beautify delivery to breast most cancers cells [84]. There are numerous kinds of Polymeric Nanoparticles, such as, Dendrimers are incredibly branched, big name-fashioned macromolecules with a well-defined, 3-dimensional structure. they could convey multiple drug molecules and target them to most cancers cells. Micelles shaped by way of self-meeting of amphiphilic block copolymers, micelles have a hydrophobic core that can encapsulate hydrophobic pills, and a hydrophilic shell that enhances solubility and stability within the bloodstream [85].

Nanocapsules are vesicular structures where the drug is restrained to a cavity surrounded by means of a completely unique polymer membrane, offering safety and managed launch of the drug. Nanospheres stable colloidal particles wherein the drug is uniformly dispersed. They may be designed to release the drug at a controlled price over a prolonged period [86].

Mechanism of action in targeting breast cancer cells

Polymeric nanocarriers (percent) are engineered to deliver therapeutic retailers immediately to

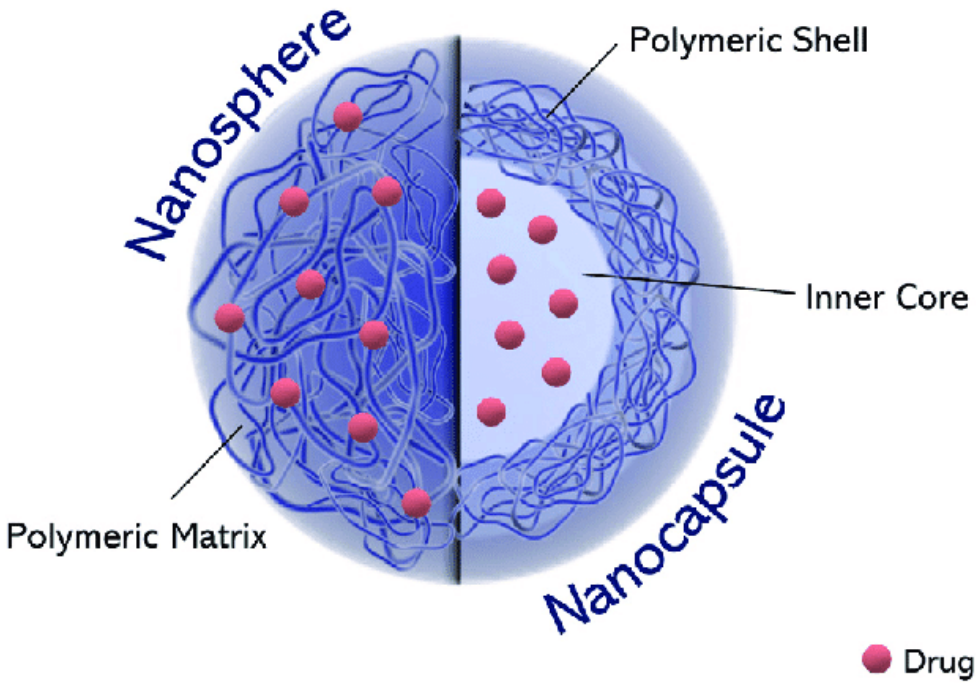

Fig. 2. Polymer Nanocarrier structure

breast most cancers cells, thereby improving treatment efficacy and lowering systemic toxicity. The concentrated on mechanisms of percent can be labeled into passive and energetic concentrated on percent exploit the EPR effect, where the leaky vasculature of tumors allows nanoparticles (within the size variety of 8 to one hundred nanometers) to accumulate greater within the tumor tissue than in regular tissues [87]. This passive concentrated on mechanism results in more advantageous drug dispersal in the tumor. ppolymeric nanocarriers can be changed with ligands, antibodies, or peptides that recognize and bind to precise receptors or antigens overexpressed on breast most cancers. Upon binding to the target receptors, percent are internalized by means of the most cancers cells through receptor-mediated endocytosis, ensuring the transport of the healing payload at once into the cells. a few percent are designed to reply to the acidic tumor microenvironment, triggering the discharge of the encapsulated drug at the website online of the tumor [88]. Others reply to precise enzymes which are overexpressed within the tumor microenvironment, leading to the selective launch of the drug. percent can be engineered to carry each healing and diagnostic retailers, allowing simultaneous treatment and tracking of the tumor reaction. can co-supply more than one drugs or integrate chemotherapy with gene remedy, improving the general remedy efficacy. The improvement of percent for breast most cancers treatment is a unexpectedly evolving discipline, with ongoing studies focused on enhancing concentrated on efficiency, reducing off-goal results, and overcoming drug resistance. those improvements in generation hold promise for bridging the therapeutic gap in breast most cancers treatment by way of turning in targeted cures to cancer cells even as minimizing systemic toxicity [89].

Advantages and limitations

polymeric nanocarriers provide great blessings within the centered treatment of breast most cancers, enhancing the therapeutic index of anticancer capsules. but, their development and clinical implementation are not without demanding situations. Ongoing research and innovation are addressing those limitations, aiming to fully harness the capability of polymeric nanocarriers in cancer therapy. benefits of Polymeric Nanocarriers covered targeted Drug delivery, more advantageous Drug stability, managed launch, Overcoming Multidrug Resistance, stepped forward Pharmacokinetics, reduced Immunogenicity and Multifunctionality [90]. Obstacles of Polymeric Nanocarriers protected Complexity of design, the improvement of polymeric nanocarriers requires sophisticated era and understanding, which may be useful resource-intensive. Scalability, production demanding situations can rise up while scaling up manufacturing for clinical and business use [91]. Biodegradability and Clearance, making sure that the materials used are biodegradable and can be cleared from the frame without inflicting damage is crucial. Regulatory Hurdles, Nanocarriers face stringent regulatory requirements for approval, that may postpone their translation from the laboratory to the health center [92].

price of production and development costs of polymeric nanocarriers may be high, impacting their accessibility and affordability. stability problems, while they decorate drug stability, nanocarriers themselves can face balance troubles for the duration of garage and shipping [93].

Clinical Trials studies

Leopoldo Sitia et al [94], developed an integrated platform using poly methyl-methacrylate nanoparticles to assess nanocarrier interactions with biological matrices. It focused on two biodegradable nanoparticle (NP) formulations, poly-ε-caprolactone (PCL3) and poly lactic-acid (PLA8), in the context of triple-negative breast cancer (TNBC). PLA8 NPs Underwent rapid degradation without tumor penetration when injected into mice. Were not internalized by the human TNBC cell line MDA-MB-231 PCL3 NPs, Exhibited longer bioavailability. Successfully reached and penetrated the tumor parenchyma in MDA-MB-231 cells. They emphasized the importance of material selection in nanocarrier design to enhance bioavailability and targeting capabilities, suggesting that PCL3 NPs could be promising for developing nanodrugs for TNBC treatment.

Kang Xiong et al [95], focused on a drug delivery system (DDS) using biodegradable PCEC nanoparticles (NPs) for co-delivering paclitaxel (PTX)and curcumin (CUR) to treat breast cancer. Nanoparticle Size, The PTX-CUR-NPs had an average size of 27.97 ± 1.87 nm. Polydispersity Index (PDI), A low PDI of 0.197 ± 0.040, indicating

uniform size distribution. Release Profile, Exhibited a controlled release of PTX and CUR without any burst effect. In Vitro Cytotoxicity, The PTX-CUR-NPs showed a higher apoptosis rate in MCF-7 cells of 64.29% ± 1.97%, compared to 34.21% ± 0.81% for free drugs. Cellular Uptake, the drug-loaded NPs were more readily taken up by tumor cells in vitro. In Vivo Tumor Inhibition, Significant inhibition of tumor growth in BALB/c nude mice xenografted with MCF-7 cells, with prolonged survival and fewer side effects than free drugs. Ki67 Expression, Lower expression in treated tumors ($p < 0.05$). TUNEL Positivity,Higher apoptosis in treated tumors ($p < 0.01$). The results suggest that the PTX-CUR-NPs DDS is a promising approach for the treatment of breast cancer, with potential for future clinical applications.

Nancy M Elbaz et al [96], explored the creation of silver nanoparticles (AgNPs) and silver/polymeric core-shell nanoparticles (NPs) with three different polymeric shells: polyvinyl alcohol (PVA), polyethylene glycol (PEG), and polyvinylpyrrolidone (PVP). These NPs were then loaded with the chemotherapy drug doxorubicin (DOX). The main focus was to assess the cytotoxic effects of these NPs on breast cancer (MCF-7) and human fibroblast (1BR hTERT) cell lines. AgNPs, Ag/PVA, and Ag/PVP NPsshowed higher cytotoxicity to MCF-7 cells compared to normal fibroblasts. DOX-Ag/PVP nanocarriers exhibited the most significant synergistic anticancer activity at low dosages. The results indicate that the NPs-based combinatorial therapy could significantly enhance the cytotoxic effect against breast cancer cells, suggesting a potential for developing more effective cancer therapeutics.

Sneha Mahalunkar et al [97], presentEd a pH-responsive folate-targeted polymer-coated gold nanoparticle (FA–CurAu-PVP NC) designed for drug delivery and therapy in breast cancer, utilizing the medicinal properties of curcumin. Curcumin Loading 40 µg/mL was loaded onto the nanoparticles. Release of Curcumin showed an 80% releaseat acidic pH. Anticancer Activity demonstrated efficient activity at lower doses, especially in ER/PR-negative breast cancer cells. Cytotoxicity, no cytotoxicity observed at the tested concentration in human breast epithelial and mouse fibroblast cell lines. In Vivo Efficacy, High antitumor efficacy shown in a preclinical breast cancer orthotopic mouse model. The study concludes that the folate-targeted nanoparticles offer a promising method for delivering curcumin directly to breast cancer cells, enhancing its therapeutic potential while minimizing effects on normal cells.

Yongmei Zhao et al [98], investigated the effectiveness of targeted polymeric nanomedicines conjugated with peptide aptamers against breast cancer. These aptamers, specifically an 8-mer (A8) and 13-mer (A13), have a high affinity for the heat shock protein 70 (HSP70) receptor on cancer cells. The nanomedicines were made using hyperbranched polymer (HBP) nanoparticles, with the anticancer drug doxorubicin (DOX) and the fluorophore Cyanine-5.5 (Cy5.5) for treatment monitoring. Targeted nanomedicines induced significant tumor regression in nude mice with MDA-MB-468 xenografts compared to controls. The DOX concentration in tumors was 5.5 times higher with targeted therapy than with free DOX, and 2.6 times higher than with untargeted nanomedicine. The results highlight the potential of aptamer-targeted nanomedicines to enhance the delivery and accumulation of therapeutic agents in tumors for cancer treatment.

Baolan Tang et al [75], focused on developing liposome ligands modified with branched biotins to target SMVT receptors, which are overexpressed in breast cancer cells. Four types of modified liposomes—Bio-Lip, Bio-Bio-Lip, tri-Bio-Lip, and Tetra-Bio-Lip—along with an unmodified version (Lip), were prepared to evaluate their targeting capabilities against breast cancer. Tri-Bio-Lip demonstrated the most potent anti-proliferative effect on breast cancer cells when loaded with the chemotherapy drug paclitaxel. In cellular uptake studies, tri-Bio-Lip showed the highest internalization ability in both mouse (4T1) and human (MCF-7) breast cancer cells, with uptake rates significantly higher than the other liposomes. In vivo studies using 4T1 tumor-bearing mice confirmed that tri-Bio-Lip had the greatest enrichment at tumor sites, aligning with the in vitro results. The research concluded that increasing the density of targeting molecules on liposomes significantly improves their ability to target breast cancer. The study suggests that the branching structure and spatial arrangement of biotin residues are crucial for binding to SMVT receptors. As a result, tri-Bio-Lip is highlighted as a promising candidate for a targeted drug delivery system in breast cancer treatment.

Rinki Verma et al [99], evaluated Methotrexate-

loaded chitosan nanoparticles (Meth-Cs-NPs) for breast cancer treatment. Methotrexate Loading 49% loaded into nanoparticles. Nanoparticle Size, Approximately 143 nm. Zeta Potential, 34 ± 3 mV. Entrapment Efficiency, 87%. In Vitro Efficacy, IC50 value of 15 µg/mL caused 50% cell death in 24 hours in MDA-MB-231 cell lines. Hemocompatibility, Meth-Cs-NPs showed **less than 2% hemolysis, indicating biocompatibility. In Vivo Pharmacokinetics Increased plasma concentration and retention time, with decreased cellular clearance compared to free Methotrexate. Anti-Tumor Efficacy, reduced tumor volume from 1414 mm^3 to 385 mm^3, versus 1414 mm^3 to 855 mm^3 with free Methotrexate. The results suggest Meth-Cs-NPs as a promising approach for breast cancer treatment, offering improved drug delivery and efficacy compared to free Methotrexate.

Table 1. Comparison among many options of Liposomes and Polymeric nanocarriers

Type of Nanocarriers	Liposomes	Polymeric NC	References
Efficacy	High efficacy due to bilayer structure mimicking cell membranes, allowing for effective drug encapsulation and targeting	High efficacy with the ability to modify surface properties for targeted delivery and controlled release	[111] [112]
Safety and Toxicity	Generally biocompatible and well-tolerated; however, some formulations may cause immune responses or toxicity.	Biodegradable materials are typically used, reducing long-term toxicity; however, polymer composition can influence biocompatibility	[113] [114]
Cost and Scalability	Production can be costly and complex, potentially limiting scalability	More cost-effective to produce and easier to scale up, depending on the polymer and method used	[115] [116]
Patient Outcomes	Clinically accepted for various treatments; patient outcomes depend on the specific formulation and disease.	Increasing clinical acceptance as research advances; outcomes are promising, especially in targeted and controlled release applications	[117] [118]

Sharmistha Chatterjee et al [100], focused on enhancing the bioavailability and anticancer efficacy of Carnosic Acid (CA) against Triple-Negative Breast Cancer (TNBC)using CA-loaded poly(lactic-co-glycolic) acid (PLGA) nanoparticles (NPs). Challenge of TNBC is hard to treat due to the absence of certain receptors, limiting treatment options to high-dose chemotherapy with nonspecific toxic effects. Formulation of CA-PLGA NPs to improve the pharmacokinetic limitations of CA. In Vitro Studies demonstrated that CA-PLGA NPs significantly induced oxidative-stress-mediated apoptotic death in MDA-MB-231 cells. Cellular Uptake Improved uptake of CA-PLGA NPs by TNBC cells compared to free CA. In Vivo Studies Showed enhanced chemotherapeutic efficacy of CA-nanoformulation over free CA without systemic toxicity. The study concludes that CA-PLGA NPs are a promising approach to address the biopharmaceutical challenges of CA and provide a new treatment option for TNBC.

Vanessa Franco Carvalho Dartora et al [101], investigated a poly (N-isopropyl acrylamide, pNIPAM) nanoparticle delivery system for treating ductal carcinoma in situ (DCIS). IC50 Reduction of Nanoparticle delivery reduced the IC50 of piplartine by 4.9 times and further by ~15 times when combined with YARA. decreased in vivo tumor incidence by 5.2 times. Drug Concentration Piplitarine concentration in mammary glands was 35.3 ± 22.4 µg/mL, much higher than in plasma (0.7 ± 0.05 µg/mL). The results suggest that the nanocarrier system significantly enhances targeted drug retention and reduces tumor development with minimal systemic exposure.

Tong Chen et al [102], explores the use of TPGS-b-PCL polymeric nanoparticles for delivering the chemotherapy drug paclitaxel (PTX). The IC50 values of T-b-P@PTX for MCF-7 cells were 543.7 ± 2.58 at 24 hours, 130.2 ± 3.54 at 48 hours, and 66.99 ± 3.43 at 72 hours. Cell. T-b-P@PTX showed a strong ability to induce cell death in MCF-7 cells. The nanoparticles were effectively internalized by the MCF-7 cells. The findings suggest that TPGS-b-PCL polymeric nanoparticles loaded with paclitaxel are a promising method for treating breast cancer, offering targeted drug delivery and enhanced anticancer effects.

COMPARATIVE ANALYSIS OF LIPOSOMES AND POLYMERIC NANOPARTICLES

In Drug Encapsulation and launch, Liposome nanocarriers show off excellent drug encapsulation potential because of their bilayer shape. they can encapsulate each hydrophilic and hydrophobic tablets, taking into consideration versatile healing payloads [103], however Polymeric NCs composed of biocompatible polymers, offer managed drug release profiles. Their tunable houses permit for sustained drug shipping, minimizing fluctuations in drug attention [104].

About targeting performance liposomes surface may be changed with ligands (e.g., antibodies) for unique tumor targeting. but, achieving uniform targeting throughout various tumor sorts stays an assignment [105], however Polymeric NCs floor functionalization allows energetic focused on. moreover, the EPR effect enables passive accumulation in tumor tissues. Polymeric nanoparticles may be tailored for tumor-precise ligand conjugation [106].

related to Biocompatibility and Toxicity, Liposomes commonly nicely-tolerated, however problems like lipid degradation and immune response might also rise up [107], however Polymeric NCs biocompatibility varies based totally on the polymer used. a few polymers (e.g., PLGA) are nicely-tolerated, whilst others may additionally reason toxicity [108].

about balance and Scalability, Liposomes at risk of aggregation, leakage, and instability throughout storage. Scalability remains a task [109]. Polymeric NCS improved stability because of robust polymer matrices. Scalability is viable, especially for FDA-approved polymers [110]. Some comparison between liposomes and polymeric nanocarriers is done in Table1.

In summary, both liposomes and percent have them deserves within the context of breast most cancers remedy. Liposomes are a more hooked up era with a clear song file of improving affected person effects, however they arrive with better costs and production complexities. PNPs, however, are emerging as a flexible and probably greater price-effective alternative, although their long-time period protection and efficacy still require further scientific validation.

The choice among these nanocarrier structures may in the end depend on the unique clinical situation, the type of drug being brought, and the economic considerations of the healthcare setting. As studies progresses, we can also see improvements that mitigate the constraints of each structure, main to advanced breast most

cancers remedies with better affected person results and popularity.

CONCLUSION

The systematic review of liposomes and polymeric nanoparticles inside the treatment of breast cancer underscores a massive stride closer to precision remedy. those nanocarriers have confirmed the ability to revolutionize therapeutic techniques by means of imparting centered drug delivery, improved efficacy, and minimized toxicity. Liposomes have proven good sized promise in scientific trials, owing to their biocompatibility and versatility in encapsulating numerous tablets. Polymeric nanoparticles, with their tunable houses and managed release mechanisms, stand out for their capability to sustain drug motion and enhance patient compliance. regardless of those improvements, challenges persist in the balance, scalability, and regulatory reputation of those nanocarriers. future studies must attention on addressing those hurdles through modern layout and manufacturing methods. moreover, exploring the synergistic outcomes of mixing more than one types of nanocarriers should lead to breakthroughs in treatment efficacy. Regulatory bodies will play a pivotal function inside the translation of nanocarrier technology from the laboratory to the hospital. ensuring protection, efficacy, and ethical issues within the development of those nanocarriers is paramount for gaining public trust and regulatory approval. In end, liposomes and polymeric nanoparticles hold big capability in improving breast most cancers remedy. Their capacity to target tumors with precision and reduce damaging effects gives a hopeful future for sufferers. As research progresses, these nanocarriers are poised to become critical components of cancer therapeutics, probably main to greater a hit outcome within the fight against breast cancer.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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