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Advances in Chemotherapy for Breast and Lung Cancers: A Comprehensive Review

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ABSTRACT:
Chemotherapy is a key component of treatment for lung and breast cancers, which account for a significant portion of the world's cancer burden, in both neoadjuvant and adjuvant settings as well as in metastatic settings. Recent developments in chemotherapeutic approaches for various cancers are summarized in this review, with a focus on new drugs, regimens driven by biomarkers, and integration with immunotherapy and targeted therapies. While immunochemotherapy combinations like atezolizumab and pembrolizumab have improved survival outcomes in triple-negative breast cancer and small cell lung cancer, innovations like liposomal formulations, nanoparticle-based delivery systems, and antibody-drug conjugates have increased efficacy and decreased toxicity. Globally, persistent problems like drug resistance, toxicity, and unequal access demand the use of strategies like precision medicine and nanotechnology. To maximise therapeutic personalisation, we investigate future prospective paths such as liquid biopsies, genetic profiling, and innovative combination medicines. This thorough examination highlights the changing role of chemotherapy in the treatment of lung and breast cancer and provides guidance for improving clinical practice and research.

Keywords: Chemotherapy, neoadjuvant, adjuvant, metastatic, toxicity, clinical practice

I. INTRODUCTION:

Lung and breast cancers are among the most common and deadly tumours worldwide, and they account for a large portion of the total cancer burden. Around 2.3 million women were anticipated to be affected by breast cancer each year in 2024, whereas 1.8 million people died from lung cancer, the primary cause of cancer-related death, globally [1]. In neoadjuvant, adjuvant, and metastatic settings for both diseases, chemotherapy—which is the systemic delivery of cytotoxic drugs to target rapidly reproducing cancer cells—remains a fundamental component of treatment [2]. Chemotherapeutic regimens in the past have frequently included broad-spectrum drugs with high toxicity and poor specificity, such as anthracyclines, taxanes, and platinum-based compounds [3]. Recent developments, however, have changed the therapeutic nature by creating new medication formulations, biomarker-driven approaches, and combinations that work well with immunotherapy and targeted therapies. While reducing side effects in patients with lung and breast cancer, these advancements have enhanced clinical results, such as overall survival and progression-free survival [4]. Nevertheless, problems including medication resistance, toxicities associated with treatment, and unequal access to new treatments around the world still exist, requiring constant study and development [5]. This thorough analysis summarises the latest developments in chemotherapy for lung and breast malignancies, including new drugs, individualised treatment plans, and new difficulties. This article attempts to give physicians and researchers a strong framework for improving cancer care by looking at clinical evidence, resistance mechanisms, and future directions.

Chemotherapy in Breast Cancer: Advances and Innovations:

Chemotherapy regimens:

Anthracyclines (Doxorubicin, Epirubicin), taxanes (paclitaxel, docetaxel), and alkylating drugs (cyclophosphamide) are commonly used in chemotherapy for breast cancer. In cases of early-stage and metastatic breast cancer (MBC), regimens such as AC-T (doxorubicin, cyclophosphamide, followed by taxanes) are common [3]. Recent developments have concentrated on lowering toxicity and enhancing drug delivery. By encapsulating the medication in liposomes, liposomal doxorubicin, a pegylated formulation, reduces cardiotoxicity, which occurs

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in 5–10% of patients at high cumulative dosages [5]. Compared to conventional doxorubicin, liposomal doxorubicin maintains efficacy with a decreased incidence of cardiac events [6].

By using albumin-mediated administration, albumin-bound paclitaxel (nab-paclitaxel) improves medication solubility and tumour penetration. According to a phase III trial, nab-paclitaxel in MBC had a 33% objective response rate (ORR) as opposed to regular paclitaxel's 19% ORR, with less hypersensitivity events [7]. Dose-dense regimens offer better results since they reduce the time between cycles. For early-stage breast cancer, the SWOG S0221 trial found that dose-dense AC-T had an 82% 5-year disease-free survival (DFS) compared to 78% with normal scheduling [8]. These developments demonstrate a move towards maximising effectiveness while reducing toxicity [4].

Subtypes of breast cancer: Chemotherapy

Treatment strategies must be tailored for the many molecular subtypes of breast cancer, such as hormone receptor-positive (HR+), HER2-positive, and triple-negative breast cancer (TNBC) [9]. Many low-risk patients can avoid needless treatment by using genetic tests like Oncotype DX and MammaPrint to estimate the probability of cancer recurrence and the need for chemotherapy in HR+ breast cancer. Numerous HR+ patients with intermediate risk can safely forego chemotherapy without experiencing any negative effects on their outcomes, according to studies [10].

Chemotherapy is used in conjunction with anti-HER2 treatments such as trastuzumab or Pertuzumab for HER2-positive breast cancer [11]. The CLEOPATRA trial showed that in HER2-positive MBC, the addition of Pertuzumab to trastuzumab and docetaxel increased overall survival (OS) and progression-free survival (PFS) from 12.4 to 18.5 months. [11]. With continuing trials investigating new drugs such tucatinib in conjunction with taxanes, dual HER2 blockage plus chemotherapy is now the norm [12]. TNBC is largely dependent on chemotherapy due to the absence of targeted therapeutic alternatives [13]. Platinum drugs, such as carboplatin and cisplatin, are beneficial in treating BRCA-mutated TNBC; among BRCA-mutant patients, the TNT study found that carboplatin had a 68% ORR compared to 33% for docetaxel [13]. In BRCA-associated TNBC, poly (ADP-ribose) polymerase (PARP) inhibitors, increase the effectiveness of chemotherapy [14].

Treatment for TNBC has changed as a result of the combination of immune checkpoint inhibitors (ICIs) and chemotherapy [15]. The significance of choosing the right chemotherapy backbone was highlighted by the IMpassion131 study, which demonstrated no benefit with paclitaxel [16]. Pembrolizumab with chemotherapy (carboplatin, paclitaxel, and anthracycline) enhanced pathological complete response (PCR) rates (64.8% vs. 51.2%) and event-free survival in early-stage TNBC, according to the KEYNOTE-522 trial [17]. The role of chemotherapy has been broadened by antibody-drug conjugates (ADCs). In HER2-low MBC (DESTINY-Breast04 study), the PFS for physician-chosen chemotherapy was 5.1 months, while that of trastuzumab, which targets HER2, was 9.9 months [18]. These ADCs combine cytotoxic payloads with targeted delivery, enhancing chemotherapy's precision [19].

Chemotherapy in Lung Cancer: Current and Emerging Strategies

Non-Small Cell Lung Cancer (NSCLC)

NSCLC, which accounts for 85% of instances of lung cancer, is treated with platinum-based chemotherapy (cisplatin or carboplatin) in conjunction with gemcitabine, pemetrexed, or taxanes. With a median overall survival of 7–8 months in advanced non-small cell lung cancer, platinum doublets were made the norm by the ECOG 1594 trial [20]. PFS is prolonged by maintenance treatment with gemcitabine or pemetrexed after induction. In non-squamous NSCLC, the PARAMOUNT study found that the PFS for pemetrexed maintenance was 6.9 months, while the PFS for a placebo was 5.6 months [21].

In NSCLC, nap-paclitaxel has becoming more popular, especially for older patients or those with concomitant conditions. When nab-paclitaxel plus carboplatin was compared to solvent-based paclitaxel plus carboplatin in a phase III trial, the ORR was higher (33% vs. 25%) and the neuropathy was lower [22]. Based on differences in drug sensitivity, histology-guided chemotherapy optimises results: gemcitabine for squamous NSCLC and pemetrexed for non-squamous NSCLC [23].

Small Cell Lung Cancer (SCLC):

Etoposide plus platinum regimens are effective in treating SCLC, which is characterised by rapid development and early metastases. In extensive-stage SCLC (ES-SCLC), response rates range from 60 to 70%. Atezolizumab was added to

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etoposide-carboplatin in the groundbreaking IMpower133 trial, increasing the median overall survival from 10.3 to 12.3 months [24]. Chemotherapy plus durvalumab increased OS to 13.0 months from 10.3 months, according to the CASPIAN study [25]. Trials are looking into different ICIs, such as nivolumab, but these immunochemotherapy regimens remain now the first-line treatment [26].

Challenges in Chemotherapy for Breast and Lung Cancers:

Drug Resistance:

Resistance to chemotherapy is a significant obstacle. The effectiveness of treatment for breast cancer is decreased by the overexpression of multidrug resistance proteins (like P-glycoprotein and MRP1) and increased DNA repair (like BRCA-mediated homologous recombination. Cancer stem cell enrichment and the activation of survival pathways such as PI3K/AKT are what promote resistance in TNBC [27]. The epithelial-to-mesenchymal transition (EMT) and tumour microenvironment variables (such as hypoxia and stromal interactions) are responsible for platinum resistance in lung cancer [28]. Combination treatments aimed at resistance pathways are one method of overcoming resistance. In preclinical models, mTOR inhibitors such as everolimus improve chemotherapy sensitivity in breast cancer [29]. ATR inhibitors and cisplatin are being studied in relation to lung cancer because they may interfere with DNA repair [30].

Toxicity and Supportive Care:

The quality of life of patients is impacted by toxicities associated with chemotherapy, including myelosuppression, neuropathy, cardiotoxicity, and nephrotoxicity. While taxanes produce peripheral neuropathy in 20–30% of individuals, anthracyclines cause progressive cardiotoxicity [31]. In lung cancer, cisplatin's nephrotoxicity and ototoxicity require close observation [32]. Advances in supportive treatment, such as antiemetics (e.g., aprepitant) and granulocyte colony-stimulating factors (G-CSF), have decreased toxicity. Personalised dosing is made possible by pharmacogenomic testing, such as DPYD genotyping for fluoropyrimidine toxicity [33]. Dose-dense regimens and liposomal formulations significantly reduce side effects while preserving effectiveness [6].

Global Access and Equity:

Advanced chemotherapies (liposomal, albumin-bound, ADCs, nanocarriers) and biomarker-guided regimens are becoming more widely available in high-income countries, but many LMICs face obstacles such as the high cost of novel agents, limited access to biomarker testing, a lack of supportive infrastructure (e.g., G-CSF, antiemetics, pharmacogenomic labs), and regulatory delays(50). If chemotherapy advancements are to reduce the incidence of breast and lung cancer worldwide, closing this gap is essential. Cost-effectiveness, generic availability of nanoparticle/ADC technologies, and scalable biomarker testing (liquid biopsy, fast genotyping) in resource-constrained environments are all areas that require implementation research. Furthermore, specific guidelines are needed that take into account patient comorbidity burden, regional drug availability, and logistical realities (such as supply chain and rural access)(34,35).

II. FUTURE DIRECTIONS:

Precision Chemotherapy and Biomarkers

By customizing therapies to each patient's unique tumour profile, precision medicine is revolutionizing chemotherapy [36]. Tumor-infiltrating lymphocytes (TILs) and PD-L1 expression predict the response to immunochemotherapy in TNBC, whereas genetic assays inform treatment choices in breast cancer [15]. Chemotherapy modifications are informed by ctDNA-based liquid biopsies that track resistance mutations in lung cancer. Combination tactics are guided by emerging biomarkers, such as homologous recombination deficiency (HRD) scores in breast cancer and TMB in lung cancer [36]. Inhibitors such as inavolisib target PIK3CA mutations in HR+ breast cancer, delaying the need for chemotherapy by over two years in advanced cases [37]. Amivantamab with chemotherapy is used to treat EGFR exon 20 insertion mutations in NSCLC, extending OS post-osimertinib progression to 18.1 months [49]. In biomarker-positive subgroups, these biomarkers increase response rates by as much as 30% [36].

Nanotechnology and Drug Delivery Systems:

By enhancing drug distribution and lowering toxicity, nanotechnology raises the therapeutic index of chemotherapy. By more efficiently targeting tumours, liposomal doxorubicin and nanoparticle cisplatin reduce systemic side effects [38]. In resistant tumours,

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taxanes based on nanoparticles exhibit promise [39]. For the best drug delivery in both malignancies, polymeric micelles and dendrimers are being researched. Hybrid nanoparticles have been investigated in recent 2025 trials for the administration of combination chemotherapy and immunotherapy, raising intratumoral drug concentrations by 50% in preclinical NSCLC animals [40]. Platinum agents and PARP inhibitors encapsulated in nanoparticles enhance PFS by 25% in TNBC with BRCA mutations in breast cancer [41].

Novel Combinations and Emerging Therapies:

A primary focus for enhancing results is on synergistic combinations [42]. Treatment options for breast cancer are expanded by ADCs such as Sacituzumab govitecan and bispecific antibodies [19]. Chemotherapy and anti-angiogenic drugs such as bevacizumab together increase PFS in non-squamous non-small cell lung cancer [43]. In NSCLC, the use of KRAS inhibitors in conjunction with chemotherapy is being investigated [44]. For HR+/HER2- MBC, datopotamab deruxtecan, which was approved in 2025, decreased the risk of neuropathy by achieving a median PFS of 6.9 months as opposed to 4.9 months with chemotherapy alone [45]. Platinum-etoposide in conjunction with bispecific T-cell engagers such as tarlatama, which was approved in 2024, produces 40% response rates after chemotherapy in SCLC [46]. Osimertinib with chemotherapy increased PFS to 25.5 months in EGFR-mutant NSCLC and decreased resistance development by 15–20% [47]. De-escalation techniques were supported by immunotherapy-chemotherapy triplets, such as pembrolizumab with Sacituzumab govitecan in PD-L1+ TNBC, which increased PFS to 11.2 months vs to 7.8 months with chemotherapy alone [48]. By 2026, these multimodal regimens may increase lasting responses by 30–40% [42].

III. DISCUSSION:

Significant advancements in chemotherapy have made treatments for lung and breast malignancies less hazardous and more effective. By delivering medication directly to tumours, new drug formulations such liposomal doxorubicin and nab-paclitaxel lessen adverse effects like nerve pain and heart damage. These developments have raised early-stage breast cancer survival rates by roughly 4% to 5%. Medication like Pemetrexed helps patients with lung cancer, particularly those with non-squamous non-small cell lung cancer, survive longer without the disease progressing. Additionally, patients with small cell lung cancer (SCLC) and triple-negative breast cancer (TNBC) have lived two to three months longer when immune treatments like pembrolizumab and atezolizumab are added to chemotherapy. In certain situations, antibody-drug conjugates (ADCs), such trastuzumab deruxtecan for breast cancer, increase survival by 40–50%, improving the precision of chemotherapy.

Drug resistance and adverse effects are among the issues that still exist, though. Because of proteins that prevent treatment or fix DNA damage, breast cancer tumours, particularly TNBC, can withstand medication. Low oxygen levels in tumours reduce the effectiveness of platinum treatments for lung cancer. Twenty to thirty percent of patients experience side effects such kidney damage and nerve discomfort, which reduces their quality of life. Supportive care has decreased these issues by 10–15%. Examples of this include medications to increase white blood cells and genetic testing to modify dosages. Another major problem is access to novel medicines, since many patients in low- and middle-income nations cannot afford medications like ADCs. Although they could be helpful, biosimilars—less expensive versions of pricey medications—are not generally accessible because of supply and regulatory concerns.

Anticipating the future, emerging technologies such as liquid biopsies and genetic testing will personalise treatment and increase response rates by as much as 30%. Treatment success rates for lung cancer and breast cancer may rise by 50% and 25%, respectively, thanks to nanotechnology, such as nanoparticles that deliver medications straight to tumours. By 2026, new combinations, such as tarlatamab for SCLC and datopotamab deruxtecan for breast cancer, may increase survival by 30–40%. These developments demonstrate the continued importance of chemotherapy, but further research and international cooperation are required to lower costs and lessen adverse effects.

IV. CONCLUSION:

Innovations in nanotechnology-based drug delivery systems, such as liposomal encapsulations, albumin-bound nanoparticles, and polymer–drug conjugates, have markedly enhanced tumor-selective chemotherapy while minimizing systemic toxicity in lung and breast cancers. The integration of biomarker-guided stratification, including

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EGFR/ALK/ROS1 profiling in non-small cell lung cancer and BRCA1/2 mutation testing in triple-negative breast cancer, has further refined therapeutic precision. Moreover, combination regimens incorporating platinum-based chemotherapy with antibody–drug conjugates and immune checkpoint inhibitors have yielded unprecedented improvements in clinical outcomes. As precision medicine, advanced drug delivery, and global health equity continue to evolve, chemotherapy—integrated with targeted and immune-based modalities—will remain a cornerstone of personalized, multidisciplinary cancer care.

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CONFLICT OF INTEREST
The authors declare that there is no conflict of interest.

ABBREVATIONS
AC-T: Doxorubicin, Cyclophosphamide, followed by Taxanes, HR+: Hormone Receptor-Positive, TNBC: Triple-Negative Breast Cancer, SCLC: Small Cell Lung Cancer, ORR: Objective Response Rate, OS: Overall Survival, PCR: Pathological Complete Response, PFS: Progression-Free Survival.

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