

Survey on Distributed AI-Enhanced Deep Learning for Predicting Chemo Response in Non-Hormone Receptor Breast Cancer

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ABSTRACT

This study offers a novel method for forecasting the response to chemotherapy in non-hormone receptor breast cancer, a difficult and complicated condition. TensorFlow-powered Spatial Temporal Integration (CNN-RNN) Architecture is used in the methods to integrate clinical data and histological images. Heuristic-driven deep learning techniques use domain-specific knowledge to build models and choose features. Using clinical knowledge, Hybrid Differential Evolution and Particle Swarm Optimization (DE-PSO) optimizes the model's parameters. Because Lime offers comprehensible justifications for the model's predictions, its adoption guarantees transparency and interpretability. Furthermore, federated learning is used in a distributed training approach to preserve scalability and safeguard patient data privacy. This method offers precision and empathy for better treatment decisions for non-hormone receptor breast cancer by fusing AI with clinical expertise.

Keywords: Healthcare; Spatial temporal integration; Breast cancer; Non-hormone Receptor Subtype; Heuristic-driven model; Deep learning.

1. Introduction

Breast cancer, a global health concern affecting millions, is a diverse and complex disease with various subtypes. Effective management is crucial, and chemotherapy is a potent treatment option. Breast cancer comprises diverse molecular subtypes, influencing how it behaves and responds to treatment [1]. Chemotherapy is often used to shrink tumors before surgery, but predicting individual tumor responses is challenging. Chemo responses, like "Complete Response," "Partial Response," "Stable Disease," or "Progressive Disease," are crucial markers for treatment effectiveness. The goal is to provide personalized, effective, and minimally invasive treatments. Understanding breast cancer's complexities, the role of chemotherapy, and predicting chemo responses are vital for improving outcomes and offering hope to those affected by this challenging disease [2].

Breast cancer subtypes provide valuable insights into the cancer's behavior, treatment response, and overall prognosis. Our understanding of these diverse molecular subtypes has transformed breast cancer diagnosis and treatment. One significant subtype, known as luminal A, is characterized by specific genetic and biological features, with positive progesterone and estrogen receptors (PR and ER). This sensitivity to hormonal therapy makes drugs like tamoxifen and aromatase inhibitors the primary treatment options. Chemotherapy may be considered in some cases. Luminal A is a prevalent subtype, representing a significant portion of breast cancer cases. Luminal B breast cancer, another common molecular subtype, shares the PR and ER positivity seen in Luminal A tumors. However, Luminal B cancers often have a higher tumor grade, indicating increased aggressiveness. These tumors exhibit characteristics of both HER2-positive and hormone receptor-positive tumors, posing challenges for treatment choices. HER2-enriched breast cancer is a distinct subtype characterized by overexpression of the HER2 receptor, leading to rapid cancer cell growth [3]. Combination therapies involving targeted therapy, chemotherapy, and hormone therapy have shown promising outcomes for this subtype.

In contrast, triple-negative breast cancer (TNBC) lacks estrogen receptors (ER), progesterone receptors (PR), and human epidermal growth factor receptor 2 (HER2). This absence makes TNBC resistant to HER2-targeted drugs and hormone therapies. TNBC represents 10-15% of all breast cancer diagnoses and is more common in women of African or Hispanic descent and those with a BRCA1 gene mutation. Treatment typically involves radiation therapy, chemotherapy, and surgery [4]. Basal-like breast cancer is another subtype with a distinct gene expression profile, often resembling basal cells in breast ducts. These characteristics contribute to its unique nature. Breast cancer encompasses diverse subtypes, each with its unique characteristics, management challenges, and treatment considerations. Non-hormone receptor breast cancer (NHRBC) is particularly complex and challenging to treat. NHRBC does not depend on progesterone or estrogen to grow, distinguishing it from hormone receptor-positive breast cancers, which are more common [5]. Since NHRBC lacks these hormone receptors, traditional hormone-based therapies are ineffective, necessitating different treatment strategies. NHRBC can be further categorized into HER2-positive and HER2-negative subgroups, each requiring specific treatment approaches. Triple-negative breast cancer (TNBC), a substantial portion of NHRBC cases, lacks expression of ER, PR, and HER2 genes. These subtypes emphasize the need for innovative treatment strategies [6]. To address the complexity of NHRBC, an advanced architectural framework combines Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs). This combination allows for the analysis of both spatial (histological images) and temporal (clinical data over time) aspects of a patient's condition. CNNs process histological images to identify tumor characteristics, while RNNs explain how the disease evolves over time in response to treatment. Domain-specific heuristics, expert-based problem-solving strategies contributed by healthcare specialists, are employed alongside Differential Evolution and Particle Swarm Optimization (DE-PSO) to ensure the optimization process aligns with clinical standards. DE-PSO enhances model precision, resulting in more accurate predictions of disease onset and treatment outcomes [7]. Improving model interpretability through collaboration with domain-specific heuristics is essential for clinician understanding and confidence in the model's recommendations, leading to better therapeutic decisions. The ultimate goal of DE-PSO is to translate research findings into clinical practice, providing tailored care to NHRBC patients by optimizing treatment for individual needs, increasing efficacy, and reducing invasiveness. This congruence between research and practical application is crucial for advancing healthcare and improving patient outcomes.

2. Literature Survey

Breast cancer, its various subtypes, the importance of effective care, and the function of chemotherapy as a therapeutic option are all covered in this survey. It also emphasizes the importance of knowing chemo reactions in order to deliver individualized and successful treatments [8]. The text goes on to discuss other breast cancer subtypes, such as luminal A, luminal B, HER2-enriched, triple-negative (TNBC), basal-like, and non-hormone receptor breast cancer (NHRBC), each with its own set of characteristics and treatment obstacles. Likewise, it introduces an innovative architectural framework that integrates Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) to examine both spatial and temporal elements of the situations of breast cancer patients. The framework attempts to increase disease prediction accuracy as well as model interpretability [9]-[10]. This emphasizes the importance of collaboration with domain-specific heuristics contributed by healthcare

specialists, model optimization using Differential Evolution and Particle Swarm Optimization (DE-PSO), and the goal of translating research findings into clinical practice to provide tailored care for NHRBC patients. Breast cancer is a complicated and varied illness with numerous subtypes each with its own set of features, genetic profiles, and therapy problems. Extensive study has been undertaken over the years to better understand these subtypes, which include luminal A, luminal B, HER2-enriched, triple-negative (TNBC), basal-like, and non-hormone receptor breast cancer (NHRBC). This research has aided our understanding of the disease and paved the road for more targeted and effective treatments [11]. The expression of estrogen and/or progesterone receptors and a slow pace of proliferation are characteristics of luminal A breast cancer. Studies have indicated that patients with luminal A cancers typically respond favourably to endocrine treatments and have a better prognosis. More specialized treatments have been created as a result of our growing understanding of the genetic and molecular roots of this subtype [12]. Another subtype of breast cancer that expresses hormone receptors is called luminal B, and it is frequently treated with more aggressive methods due to its increased rate of growth. Finding indicators that can forecast a patient's reaction to chemotherapy and targeted treatments has been the main goal of research on luminal B breast cancer. Human epidermal growth factor receptor 2 (HER2) overexpression is a hallmark of HER2-enriched breast cancer [13]. The introduction of HER2-targeted treatments, including trastuzumab, as a result of research has greatly improved patient outcomes for those with this subtype.

One of the most aggressive subtypes of TNBC is the lack of HER2 and progesterone receptors. In order to address the dearth of targeted therapeutics, a great deal of research has been conducted on TNBC with the goal of discovering novel therapy options, such as immunotherapies and PARP inhibitors. Similar to triple negative breast cancer, basal-like breast cancer is frequently linked to unfavourable results. Studies have revealed the molecular processes that underlie this subtype and possible weaknesses that could be used for tailored treatment [14].

Numerous breast cancer subtypes that lack hormone receptor expression are included in NHRBC. Studies have brought attention to this group's heterogeneity and the necessity for individualized treatment plans and the creation of new therapeutic alternatives. After chemotherapy, a complete response indicates that there is no longer any discernible malignancy. Reaching a CR is an important therapeutic objective since it frequently leads to better long-term results. Research in this field focuses on finding the elements and biomarkers linked to reaching CR as well as tactics for sustaining this response. A partial response to chemotherapy denotes a notable decrease in the size of the tumor or the amount of malignancy. Research projects seek to improve the definition of PR criteria, evaluate the effect of PR on survival rates, and optimize treatment plans in order to maximize PR rates. It is implied by stable disease that with chemotherapy, the tumor's size or the cancer's burden essentially stays the same. Even while SD might not show a noticeable decrease in tumor size, it is still a useful response because it shows that the cancer is not spreading. Research looks at how long SD lasts, what it means clinically, and how to change it into a more positive response. A tumor's growth or cancer burden increasing in spite of chemotherapy is referred to as progressive disease. PD is an indication of the inadequacy of the existing treatment plan. This field of study investigates the causes of treatment resistance and potential solutions using alternative medicines, such as immunotherapies or targeted drugs, to salvage the situation [15]-[17]. Research is still being done to determine the predicted variables and biomarkers that are associated with chemotherapy responses. Scientists are investigating

biological markers such as proteomics and genomes to forecast a patient's reaction to a particular chemotherapy regimen. This data helps with treatment customization to increase efficacy and reduce side effects. Novel strategies for treating breast cancer are being investigated to enhance chemo responses. To maximize response rates and reduce side effects, research focuses on combining chemotherapy with immunotherapies, targeted treatments, and other innovative drugs. In order to maximize responses, tailored therapy regimens that take into account each patient's distinct genetic composition and tumor properties are becoming more and more crucial. Medical pictures like MRIs, mammograms, and histology slides can have their spatial information extracted by Convolutional Neural Networks (CNNs) with great skill [18].

CNNs are used by researchers to automatically identify and categorize tissue abnormalities, microcalcifications, and lesions related to breast cancer. By doing this, they help to optimize biopsy recommendations and enhance the early diagnosis of cancer. Because they are so good at modeling sequential data, recurrent neural networks, or RNNs, are perfect for capturing the temporal elements of patients' illnesses. RNNs are used in breast cancer research to examine longitudinal clinical data, such as therapy responses, tumor features over time, and patient histories. This helps monitor the course of the illness and forecast patient outcomes. A comprehensive examination of breast cancer cases is made possible by the synergistic coupling of CNNs and RNNs. Researchers may now combine the temporal and spatial dimensions of patient data, offering a more complete picture of the illness. Histological image analysis and longitudinal clinical data are used to greatly improve the predictive power of treatment response, prognosis, and diagnosis of breast cancer. Personalized therapy recommendations can be provided by researchers thanks to sophisticated architectural frameworks that include CNNs and RNNs [19]. Treatment regimens can be customized to optimize effectiveness and reduce adverse effects by taking into account the distinct spatial features of each patient's tumor as well as their changing clinical history.

Real-time monitoring and intervention tactics are supported by CNNs and RNNs that integrate spatial and temporal data. For example, it enables timely modifications to the treatment plan and the early identification of treatment resistance. In the end, this proactive strategy may enhance patient outcomes and quality of life. Specialists in the medical field bring in-depth knowledge of the detection and management of breast cancer as well as critical domain-specific heuristics. By combining clinical guidelines, patient data, and tumor features with these heuristics, machine learning models are guaranteed to be reliable and applicable to actual medical practice. Machine learning models become more interpretable and in line with clinical standards by including domain-specific heuristics. This makes it easier for medical practitioners to comprehend the predictions and choices made by these models, which makes it easier to integrate them into clinical workflows. In the context of breast cancer modeling, optimization approaches such as Differential Evolution and Particle Swarm Optimization (DE-PSO) have gained popularity. By optimizing model parameters and feature selection, these techniques raise the predicted accuracy and precision of the model. By optimizing parameters and features, DE-PSO approaches help machine learning models to be refined [20]. By ensuring that the model can more accurately distinguish between benign and malignant breast lesions, this procedure improves diagnosis and prediction precision. There is great therapeutic potential in integrating DE-PSO into breast cancer models. By employing these strategies to enhance the model, healthcare professionals can help patients receive better care by reducing misdiagnoses and helping them make more educated

treatment decisions. Patients with Non-Hormone Receptor Breast Cancer (NHRBC) are a distinct subgroup with particular therapeutic requirements. Since many patients do not respond well to conventional hormone-targeted therapy, it is imperative that their care be customized. The goal of research is to find novel ways to treat cancer, such as individualized therapy techniques and cutting-edge treatments. Reducing the level of invasiveness associated with breast cancer therapy is a top aim. Research in this area concentrate on creating therapeutic approaches that are less forceful yet still very effective. This strategy seeks to lessen the psychological and physical toll that treatments take on NHRBC patients in an effort to enhance their quality of life. Improving treatment efficacy for breast cancer is critical, especially for individuals with non-hormonal breast cancer (NHRBC), who frequently have more aggressive disease characteristics [21].

In order to improve outcomes and survival rates, research efforts focus on refining current medications and creating new ones that are especially suited to the biological features of NHRBC. A major area of attention for breast cancer research is the personalization of care. Healthcare professionals can optimize therapy outcomes while reducing unfavourable effects by customizing care to each NHRBC patient's specific genetic, molecular, and clinical factors. The key to improving the treatment of breast cancer patients is the use of research findings in clinical settings. Research attempts to close the knowledge gap between bench-to-bedside breakthroughs in the laboratory and NHRBC patients' access to the most recent therapeutic advances. Patient-centered outcomes, including quality of life, tolerance of treatment, and long-term survivability, are becoming more and more important in research. Patients with non-Hodgkin lymphoma (NHRBC) receive tailored care that considers their overall requirements as well as the biological elements of the illness.

2.1. Problem Statement

Breast cancer's complexity arises from its various molecular subtypes, requiring precise predictive models due to varying preoperative chemotherapy outcomes. Previous methods overlooked the importance of molecular subtypes, leading to suboptimal treatment plans and unpredictable patient responses. Breast cancer prediction models have underutilized the integration of clinical data sources like clinical records and histopathology images. Deep learning models' "black box" nature can hinder clinician trust and understanding of predictions. Model performance suffers from insufficient hyperparameter tuning, architectural configuration, and feature selection. Integrating patient records while preserving data security has been challenging. A novel approach integrates Spatial Temporal Integration (CNN-RNN) architecture, the Tensorflow Deep Learning Framework, heuristic-driven deep learning, and the Hybrid DE-PSO algorithm to address these limitations.

3. Conclusion

Research on breast cancer subtypes, including basal-like, NHRBC, TNBC, luminal A, luminal B, HER2-enriched, and TNBC, has significantly improved patient outcomes and personalized treatment plans. Integrating advanced neural network architectures, particularly RNNs and CNNs, enhances breast cancer analysis, providing precision and tailored therapy suggestions. Healthcare experts' domain-specific heuristics guide machine learning model development, ensuring clinical compliance and interpretability. The ultimate goal is translating research into clinical practice, with a focus on improving therapy efficacy, reducing invasiveness, and customizing care,

especially for NHRBC patients, emphasizing patient-centered outcomes and a higher quality of life for breast cancer patients.

Declarations

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The study has not received any funds from any organization.

Competing Interests Statement

The authors have declared no competing interests.

Consent for Publication

The authors declare that they consented to the publication of this study.

Authors' Contributions

All the authors took part in literature review, research and manuscript writing equally.

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