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Pre- and Post-chemotherapy Laboratory Evaluation in Women with Stage IIIB Breast Cancer

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ABSTRACT

Background: Chemotherapy is a modality for breast cancer (BC) treatment, particularly to reduce cancer size within the affected breast and lymph nodes before surgery. It employs anti-cancer (cytotoxic) medicines to kill cancer cells; however, it has significant adverse effects, including hematological disturbance, renal disorder, and hepatotoxicity. Laboratory evaluation is an important component for ensuring chemotherapeutic safety for BC patients.
Objectives: To assess the laboratory parameters features before and after chemotherapeutic treatment in type IIIB BC patients.
Materials and methods: This laboratory-based retrospective study included medical record data of 90 adult female BC stage IIIB patients who had chemotherapy at a tertiary-level hospital. Laboratory results were collected from each patient before and after the chemotherapy procedure, which included hematological and clinical chemistry parameters. From the hematological parameters, several inflammatory hematological ratios were calculated. Statistical analysis was performed to compare laboratory parameters before and after chemotherapy intervention using the Paired *T-test* or the Wilcoxon test based on data distribution.
Results: Following chemotherapy, there are significant drops in leukocytes (P-value = 0.002), erythrocytes (P-value < 0.001), and hemoglobin (P-value < 0.001). In addition, the leukocyte differential count revealed a decrease in the percentage of eosinophils (P-value = 0.006) and an increase in the percentage of monocytes (P-value < 0.001). Upon an inflammatory hematological ratio investigation, we discovered monocyte-to-lymphocyte ratio and platelet-to-lymphocyte ratio elevation (P-value = 0.003 and 0.030, respectively) and neutrophil-to-monocyte ratio reduction (P-value = 0.002) following chemotherapy. Creatinine and aspartate transaminase were the blood chemistry parameters that differed significantly before and after chemotherapy (P-value = 0.028 and P-value = 0.038, respectively).
Conclusion: Following BC chemotherapy, several laboratory changes, including bicytopenia, shifted leukocyte differentials, hematological inflammatory ratio change, and altered renal and hepatic function indices, were observed.
Keywords: Breast Cancer; Chemotherapy; Clinical Chemistry; Hematological indices; Laboratory.

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INTRODUCTION

Treatment for breast cancer (BC) typically involves a variety of techniques, including surgery, hormonal therapy, radiotherapy, chemotherapy, and immunotherapy. Treatment options vary depend-

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ing on age, clinical stage, tumor feature (which incorporate hormone receptor status and histological findings), and the patient's general condition [1]. In the early stages, most women can be chosen for breast-conserving surgery with radiation or mastectomy, which have similar risks regarding local recurrence and overall survival (OS) [2]. Meanwhile, for advanced breast cancer (ABC), several variables should be considered before administering systemic treatment, including the oestrogen receptor-beta (ER2) and human epidermal growth factor receptor 2 (HER2) expression, phosphatidylinositol-4,5-bisphosphate 3-kinase catalytic subunit alpha (PIK3CA) mutation status in ER-positive ABC, BC gene 2 (BRCA2) status in her2-negative ABC, and programmed death ligand 1 (PD-L1) expression in triple-negative ABC in instances involving potential target therapies. Other considerations include prior therapies and adverse reactions, disease-free interval (DFI), tumor burden (metastatic disease), biological age, comorbidities (such as organ dysfunction), performance status (PS), menopausal state (for endocrine therapy), necessity for rapid disease control, socioeconomic and psychological aspects, therapy availability, and patient choice [3]. In invasive and inoperable BC, whether in stage I, II, III, or IV, chemotherapy is typically administered first to reduce the cancer size within the affected breast and lymph nodes [4].

Chemotherapy is a typical treatment for BC that employs anti-cancer (cytotoxic) medicines to kill cancer cells [3]. As the incidence of BC rises at an alarming rate, so does the use of chemotherapy medications [4]. Chemotherapy can be administered as a combination or sequential single-agent treatment. Sequential monotherapy is frequently chosen to lessen the toxicity risk. Patients with rapid clinical advancement, life-threatening visceral metastases, or who require immediate symptom or disease management can be considered for combination chemotherapy options [3].

Chemotherapy drugs are classified into several classes, including anthracyclines (e.g., doxorubicin and epirubicin), taxanes/microtubule-damaging agents (e.g., docetaxel and paclitaxel), antimetabolites (e.g., capecitabine and gemcitabine), platinum-based drugs (e.g., cisplatin, oxaliplatin, and carboplatin), and alkylating agents (e.g., cyclophosphamide and chlorambucil) [1]. Although they have demonstrated clinical benefits in treating BC, whether as single or combination therapies, all of these medications have adverse effects that must be monitored. Anthracyclines, for example, are linked to dose-dependent irreversible cardiotoxicity [5]; taxanes may cause neurological toxicity [6]; platinum-based drugs, particularly cisplatin, can induce nephrotoxicity [7]; and alkylating agents can cause hematological toxicity (presented as anemia, thrombocytopenia, and neutropenia) [8]. Chemotherapeutic drugs can also cause hepatotoxicity, including drug-induced hepatitis, steatohepatitis, hepatic veno-occlusive disease, liver fibrosis, and liver failure [9]. Meanwhile, nephrotoxicity can cause acute kidney injury (due to tubulointerstitial nephritis, tubular injury, glomerular disease, and thrombotic microangiopathy), chronic kidney disease (CKD), and electrolyte imbalance [10]. All of this data confirmed that chemotherapy should be done with careful monitoring.

Laboratory tests are an example of a tool utilized for evaluating chemotherapy efficacy and safety. A study presented that from a multivariate analysis, neutrophil-to-lymphocyte ratio (NLR) can determine pathological complete response following neoadjuvant chemotherapy implementation (P-value = 0.04). Meanwhile, the hemoglobin/red-cell distribution width (Hb/RDW) ratio significantly predicted disease-free survival (DFS)(P-value = 0.04) [11]. Another index consisting of neutrophils, lymphocytes, and platelets, named systemic immune-inflammation index (SII) has a significant association with OS in BC patients receiving neoadjuvant chemotherapy, whereas patients with low SII ($< 547 \times 109/L$) had extended OS (65 vs. 41 months, P-value = 0.017, hazard ratio = 3.24, 95% CI = 1.23-8.55) [12]. These findings support evidence of the utilization of peripheral blood-derived indices as prognostic and therapeutic response prediction in BC cases undergoing chemotherapy.

Patients with stage IIIB BC requiring neoadjuvant or adjuvant chemotherapy have a significant risk of damage to various organs, including the liver, kidneys, and hematopoietic cells. Thus, blood testing is required during chemotherapy to ensure safety [13]. However, it mainly responds after symptoms appear, not as a prevention measure, which creates a need to understand the specific changes in laboratory results for this high-risk group to create better monitoring systems that can give early signs of organ problems. Therefore, the objective of this study was to examine the alterations in laboratory markers before and after treatment in patients with stage IIIB BC. This study is crucial since it may serve as a foundation for more comprehensive monitoring of chemotherapy effects based on widely tested laboratory indicators.

MATERIALS AND METHODS

This laboratory-based retrospective study included medical record data of adult female BC patients who were referred to Dr. Mohammad Hoesin General Hospital, Palembang, Indonesia, a tertiary-level hospital, between January and December, 2022. The demographic data only consisted of the patients' age. All patients were in stage IIIB BC underwent chemotherapy, either as monotherapy or combination (or sequential) therapy for six cycles (approximately five to six months following chemotherapy initiation). Participants with smoking, coffee and alcohol consumption, inflammatory disease and other malignant diseases were excluded. The study was approved by the Ethics Committee of the Faculty of Medicine, Universitas Sriwijaya (approval number: 234-2023). Informed consent was not needed, as the study utilized retrospective medical record data.

Samples were collected using a total sampling procedure, with a minimum of twenty-five samples required for each group (pre- and post-chemotherapy), determined based on white blood cell (WBC) count data from a previous study [14]. The calculation is available below [15]:

$$\text{Sample size } (n) = \frac{(\sigma_1^2 + \sigma_2^2)(Z_{1-\beta} + Z_{1-\alpha/2})^2}{d^2}$$

$$= \frac{(0.7^2 + 1.1^2)(0.8 + 1.96)^2}{1^2}$$

$$= \frac{(0.49 + 1.21)(2.76)^2}{1^2}$$

$$= 22 + 2.2 \quad \text{(considering 10\% dropout)}$$

$$\approx 25 \text{ patients per group}$$

d = Difference in means of two group (effect size)

σ_1 = Standard deviation (SD) of group 1
σ_2 = SD of group 2
$Z_{1-\beta}$ = Power (80% or 0.8)
$Z_{1-\alpha/2}$ = Critical value and a standard value for the respective level of confidence (at 95% confidence interval/CI it is 1.96 and at 99% CI it is 2.58)

Laboratory results, consisting of hematological and clinical chemistry parameters, were obtained for further analysis. Hematological markers were composed of hemoglobin (Hb), erythrocyte, leukocyte, platelet, and differential counts percentage (basophil, eosinophil, neutrophil, lymphocyte, monocyte). Meanwhile, clinical chemistry markers consisted of aspartate aminotransferase (AST), alanine aminotransferase (ALT), albumin, urea, and creatinine. Following compilation of these data, calculation of following hematological inflammatory indices were done: NLR, monocyte-to-lymphocyte ratio (MLR), platelet-to-lymphocyte ratio (PLR), platelet-to-monocyte ratio (PMR), neutrophil-to-monocyte ratio (NMR), lymphocyte-to-white blood cell ratio (LWBC), Hb/albumin ratio, Hb/creatinine ratio, albumin/creatinine ratio, neutrophil percentage-to-albumin ratio (NPAR), monocyte percentage-to-albumin ratio (MPAR), and platelet-to-albumin ratio (PAR). For PLR and PMR, calculation is based on the absolute count of lymphocytes and monocytes, not the percentage of these leukocyte types.

Data distribution and normality testing were performed using Kolmogorov-Smirnov (sample size >50) or Shapiro-Wilk (sample size <50) tests. The results of these tests guided as a basis for univariate analysis and data presentation, where parameters with normal distribution will be presented as mean ± standard deviation (SD), and abnormal distribution will be shown as median (interquartile range/IQR). Bivariate analysis was performed to compare laboratory parameters before and after chemotherapy intervention using the Paired *T-test*, or Wilcoxon test or based on data distribution. This process was done using IBM Statistical Package for Social Sciences (SPSS) Statistics version 27.0 (Armonk, New York, IBM Corp., United States). Statistical significance was determined at a P-value of < 0.05.

RESULTS

The current study involved 144 patients during the examination period. Following the completion of the inclusion and exclusion criteria, ninety patients were selected for further analysis in this research (Figure 1). The patients' average age is 50.61 ± 9.94 years. Most participants (60, 66.67%) are between the ages of 40 and 59 years, followed by those who are ≥ 60 years (18, 20%), and those under 40 (12, 13.33%).

Several alterations can be marked following the chemotherapy process in stage IIIB BC patients in our study. Post-chemotherapy blood tests revealed a condition called bicytopenia, which is marked by a significant drop in both leukocytes (P-value = 0.002) and erythrocytes (P-value = 0.001), as well as a drop in hemoglobin (P-value = 0.001). This is a frequently seen outcome after the treatment. Following chemotherapy, the leukocyte differential count revealed a decrease in the percentage of eosinophils (P-value = 0.006) and an increase in the percentage of monocytes (P-value = 0.001) as shown in Table 1.

Among the blood chemistry parameters analyzed, only creatinine and ALT showed significant difference. (P-value = 0.028 and P-value = 0.038, respectively). Meanwhile, no change (P-value > 0.05) was noted regarding albumin, urea, and AST following chemotherapy (Table 2).

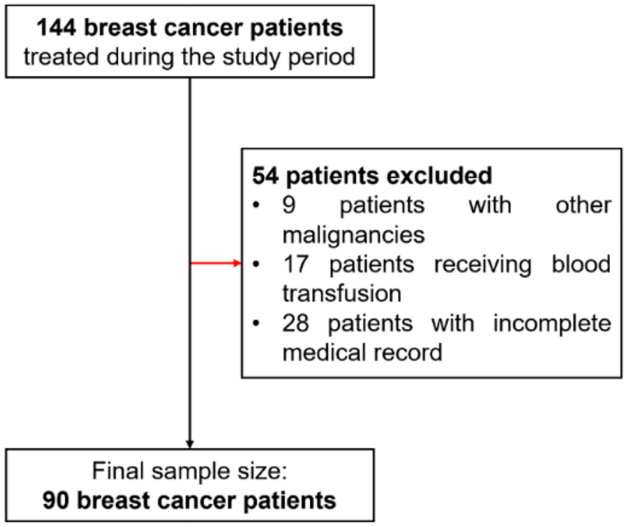

Figure 1. Flow chart of the studied patients.

The results revealed that MLR (P-value = 0.003) and NMR (P-value = 0.002) showed a substantial shift following chemotherapy, which is consistent with monocyte elevation in the post-chemotherapy group, in contrast to lymphocyte and neutrophil percentages, which remained unchanged. Interestingly, whereas the percentage of platelets and lymphocytes did not change significantly (P-value > 0.05 after chemotherapy, the PLR value significantly increased from before to after chemotherapy (P-value = 0.030) as indicated in Table 3.

DISCUSSION

The current study assessed the hematological and biochemical (including inflammatory) impacts of chemotherapy administration in stage IIIB BC patients. We observed several main laboratory changes, including bicytopenia, eosinophil reduction, monocyte elevation, creatinine reduction, and inflammatory index alteration. These changes are mainly due to the myelosuppressive effects of chemotherapy, which inhibit the normal hematopoiesis process and cytokine activity, and are also associated with depolymerization prevention, mitotic inhibition, and apoptosis promotion in blood cells [16].

The observed bicytopenia, a significant decrease in both leukocytes (P-value = 0.002) and erythrocytes (P-value = 0.001), is a predictable consequence of chemotherapy's myelosuppressive effects. This myelosuppression results from chemotherapeutic drugs' immediate cytotoxic influence on hematopoietic stem cells in the bone marrow, which disrupts erythropoiesis and leukopoiesis [17]. The fundamental process includes deoxyribonucleic acid (DNA) damage, apoptosis induction, and disturbance of the cell cycle, all of which contribute to a decrease in red blood cell (RBC) production and maturation, as well as several WBC lineages [18]. The medical effects are serious; reduced WBC count and low RBC count increase the risk of infection and anemia, respectively.

The altered leukocyte differential count, showing a decrease in eosinophils (P-value = 0.006) and an increase in monocytes (P-value = 0.001), provided further insight into the chemotherapy's impact. Eosinophil reduction is most probably due to chemotherapy's general cytotoxic effects on

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Table 1. Hematologic laboratory characteristics pre- and post- chemotherapy in breast cancer stage IIIB patients*.

Variables	Pre	Post	P-value
Hb (g/dL)	11.64±1.30, n=90	10.70±1.44, n=90	0.001^a
Erythrocyte ($\times 10^6/\mu$L)	4.18 ± 0.65, $n = 90$	3.74 ± 0.60, $n = 90$	0.001^a
Leukocyte ($\times 10^3/\mu$L)	8.35 ± 4.58, $n = 90$	6.24 (4.40), $n = 90$	0.001^b
Platelet ($\times 10^3/\mu$L)	332.16 ± 131.40, $n = 90$	329.21 ± 117.36, $n = 90$	0.818^a
Eosinophil (%)	2.00 (3.00), $n = 84$	1.00 (2.00), $n = 78$	0.012^b
Neutrophil (%)	61.27 ± 11.81, $n = 84$	59.69 ± 16.17, $n = 78$	0.619^a
Lymphocyte (%)	27.07 ± 10.20, $n = 84$	26.56 ± 11.16, $n = 78$	0.417^a
Monocyte (%)	7.00 (3.00), $n = 84$	11.29 ± 7.17, $n = 78$	0.001^b

* Abbreviations: Hb = Hemoglobin.
Note: Data are presented as mean ± standard deviation (SD) or median (IQR). p-value is based on ^{a}Paired t-test, ^{b}Wilcoxon test.

Table 2. Blood chemistry characteristics pre- and post-chemotherapy in breast cancer stage IIIB patients *.

Variables	Pre	Post	P-value
AST (U/L)	23.00 (17.00), $n = 90$	22.00 (9.00), $n = 90$	0.339^b
ALT (U/L)	20.00 (14.50), $n = 90$	17.00 (12.00), $n = 90$	0.038^b
Albumin (g/L)	4.10 (0.60), $n = 24$	3.83 ± 0.56, $n = 30$	0.478^b
Urea (mg/dL)	21.43 ± 9.06, $n = 90$	20.63 ± 10.27, $n = 90$	0.425^a
Creatinine (mg/dL)	0.76 ± 0.18, $n = 89$	0.69 (0.18), $n = 90$	0.028^b

* Abbreviations: AST = Aspartate transaminase, ALT = Alanine transaminase.
Note: Data is presented as mean ± standard deviation (SD) or median (IQR). P-value is based on aPaired *T-test*, bWilcoxon test.

Table 3. Inflammatory index data pre- and post-chemotherapy in breast cancer stage IIIB patients*.

Variables	Pre	Post	P-value
NLR	2.54 (1.94), $n = 84$	2.56 (2.93), $n = 78$	0.727^b
MLR	0.31 (0.15), $n = 84$	0.40 (0.22), $n = 78$	0.001^b
PLRc	164.12 (119.21), $n = 84$	299.94 (217.62), $n = 78$	0.004^b
PMRc	532.15 (271.15), $n = 84$	643.45 (712.05), $n = 78$	0.530^b
NMR	8.14 ± 3.15, $n = 84$	7.00 (5.51), $n = 78$	0.002^b
LWBC	0.27 ± 0.10, $n = 84$	0.27 ± 0.11, $n = 78$	0.411^a
Hb/albumin	2.81 (0.44), $n = 27$	2.83 (0.38), $n = 84$	1.000^b
Hb/creatinine	16.03 ± 3.50, $n = 89$	15.73 ± 3.92, $n = 90$	0.408
Albumin/creatinine	5.50 ± 1.28, $n = 24$	5.58 ± 1.47, $n = 30$	0.372^a
NPAR	16.03 ± 5.41, $n = 22$	17.86 ± 4.37, $n = 25$	0.274^a
MPAR	1.69 (1.05), $n = 22$	2.34 ± 0.78, $n = 25$	0.135^b
PAR	89.46 ± 33.93, $n = 24$	100.06 ± 37.64, $n = 30$	0.164^a

* Abbreviations: LWBC = Lymphocyte-to-white blood cell ratio, MLR = Monocyte-to-lymphocyte ratio, MPAR = Monocyte percentage-to-albumin ratio, NLR = Neutrophil-to-lymphocyte ratio, NMR = Neutrophil-to-monocyte ratio, NPAR = Neutrophil-to-albumin ratio, PAR = Platelet-to-albumin ratio, PLR= Platelet-to-lymphocyte ratio, PMR = Platelet-to-monocyte ratio.
Note: Data are presented as mean ± standard deviation (SD) or median (IQR). P-value is based on a Paired t-test^a, Wilcoxon test^b, and^c calculation is based on the absolute count of lymphocytes and monocytes, not the percentage of these leukocyte types.

bone marrow progenitor cells [19]. Furthermore, eosinophilia is frequently associated with enhanced tumor activity and growth, which can be alleviated by the chemotherapy procedure [20]. Meanwhile, higher monocyte counts may relate to chemotherapy's modulatory effect on monocyte penetration into the bloodstream and mobilization to tumor locations. The number of CD3-CD14+CD16- monocytes in the BC group increased after five cycles of doxorubicin treatment, then dropped sharply after the fifth cycle, and then rose again after three cycles of paclitaxel treatment [21]. It has also been observed that chemotherapy can influence the pro-tumor and anti-tumor ability of monocyte/macrophage lineages [22].

The substantial elevations in both MLR and PLR support the existence of a complex inflammatory response. This is especially interesting because there is a significant difference in PLR before and after chemotherapy, even though the percentages of platelets and lymphocytes stayed the same. On the contrary, there is a considerable decrease in NMR after the chemotherapy procedure. An increase in MLR can be linked to a worse prognosis for the patient and may indicate

that there are more immunosuppressive myeloid cells in the peripheral blood, like MDSCs. These cells are often found in more aggressive and/or chemo- or radioresistant tumors [23]. In addition, it shows that the body is moving into a pro-inflammatory state. This may be connected to the production of inflammatory cytokines and chemokines by damaged immune cells and tissues, which can change the outcomes for patients [24]. Meanwhile, PLR elevation is related to the chemotherapy-induced suppression of lymphocytes (immune cells) along with a relative increase in platelet count, which is considered an inflammatory marker during cancer treatment [25]. Reduced NMR ratio, on the other hand, may show a higher chance of developing symptoms, which is linked to a higher chance of survival [26].

The slight but statistically significant decrease in creatinine and AST post-chemotherapy suggests a potential reduction in tumor burden. This finding could be linked to variable tubular creatinine secretion in cancer patients, driven by changes in filtration marker production and nonrenal waste elimination [27]. However, studies have found that chemotherapy's impact on kidney function changes is typically minor and reversible, such as during cyclophosphamide and vemurafenib treatment [28, 29]. Additionally, reduced SGPT level following chemotherapy, which were still within the normal range, were aligned with the a previous study [30], indicated the potential safety of the chemotherapeutic regimens used in the current investigation.

The current study has several limitations. First, the sample size in this study was relatively small compared with previous studies. In addition, the study does not classify specific drug types for analysis purposes. Although we are aware of this issue, our practice has various regimen strategies, which means further classification will reduce our sample to less than the minimum sample size. Furthermore, this study only enrolled stage IIIB BC patients, limiting its generalizability, although it is useful for assessing chemotherapy effects in specific BC stages. Lastly, the retrospective nature of the study can be considered as another limitation, as it relied solely on pre-existing medical records.

CONCLUSION

The current investigation reported numerous laboratory changes before and after chemotherapy, including bicytopenia, shifts in leukocyte differentials, transformations in hematological inflammatory ratios, and alterations in renal and hepatic function indices. Future research should investigate the molecular basis of these changes, including immediate cytotoxic effects, compensatory immunological responses, and possible shifts in cytokine signaling pathways. Furthermore, subsequent studies should investigate the functional consequences of these changes, the relationship between hematological parameters and clinical outcomes, and the identification of potential therapeutic targets to reduce the side effects of chemotherapy. Moreover, future studies can utilize biomarkers with significant findings in this study for their predictive abilities, along with correlation in determining liquid biopsy requirement and molecular subtyping to guide treatment decisions.

ETHICAL DECLARATIONS

Acknowledgments

None.

Ethics Approval and Consent to Participate

The study protocol was approved by the Ethics Committee of Faculty of Medicine, Universitas Sriwijaya (approval number: 234-2023). Consent to participate is not applicable since this study used data from the medical record (retrospective study).

Consent for Publication

Not applicable (no individual personal data included).

Availability of Data and Material

Data generated during this study are available from the corresponding author upon reasonable request.

Competing Interests

The authors declare that there is no conflict of interest.

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Authors' Contributions

Conceptualization: PL; Methodology: PL, ER, and MU; Software: PL and TPU; Validation: PL, ER, MU, and TPU; Formal analysis: PL, YPW, and TPU; Investigation: PL, YPW, and RAR; Resources: PL and MU; Data curation: PL, YPW, and RAR; Writing the original draft preparation: PL, YPW, and TPU; Writing-review and editing: PL and TPU; Supervision: PL, ER, and MU. All authors have read and approved the final version of the manuscript.

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