

Examining Pre-and Post-chemotherapy Effects on Haemoglobin Level and Platelet Count in Breast and Colorectal Cancer Patients: A Georgetown Public Hospital Corporation Oncology Clinic Study (January 2020-December 2023)

Amarnauth Narain^{1*}, & Keyanne Williams¹

College of Medical Sciences, University of Guyana, Turkeyen, Georgetown, Guyana

*Corresponding author: Amarnauth Narain, College of Medical Sciences, University of Guyana, Turkeyen, Georgetown, Guyana.

Submitted: 07 July 2025 Accepted: 14 July 2025 Published: 21 July 2025

 <https://doi.org/10.63620/MKSSJCR.2025>.

Citation: Narain, A., & Williams, K. (2025). Examining pre- and post-chemotherapy effects on haemoglobin level and platelet count in breast and colorectal cancer patients: A Georgetown Public Hospital Corporation oncology clinic study (January 2020–December 2023). *Sci Set Journal of Cancer Research*, 4(4), 01-14.

Abstract

Aim: Chemotherapy is an essential treatment for breast cancer (BC) and colorectal cancer (CRC), but it often results in significant haematological side effects, such as changes in haemoglobin levels and platelet counts. This study aims to evaluate the effects of chemotherapy on haemoglobin level and platelet count in breast and colorectal cancer patients.

Study Design: Retrospective Cohort Study

Place and Duration of Study: The study was conducted at the oncology clinic of Georgetown Public Hospital Corporation (GPHC), Guyana, from January 2020 to December 2023.

Methodology: The study included 220 breast cancer cases and 30 colorectal cancer cases. Mean Haemoglobin (Hb) levels and platelet (Plt) counts pre- and post-chemotherapy were analysed through Paired-Samples t- tests, while linear regression was used to analyse the post- chemotherapy values against predictors such as stage of cancer and treatment regimen, gender and ethnicity.

Results: The mean age for breast cancer patients was 52.51 ± 9.0 whereas, for colorectal patients it was 54.20 ± 9.18 . The most prevalent breast cancer was that of invasive ductal carcinoma (93.2%), while the most prevalent type of colorectal cancer was colon cancer (63.3%). Adriamycin and cyclophosphamide (78.6%) were the primary treatment regimen for breast cancer patients. Furthermore, 50 % of colorectal cancer patients were primarily on the regimen of folinic acid, fluorouracil and oxaliplatin (FOLFOX). Statistically significant differences were found in both haemoglobin levels and platelet counts before and after chemotherapy for both groups. For breast cancer patients, the mean difference in haemoglobin levels and platelet counts were 0.71 g/dl and $32.39 \times 10^9/L$ respectively. For colorectal cancer patients, the mean difference in haemoglobin levels and platelet counts were 0.81 g/dl and $73.43 \times 10^9/L$ respectively.

Conclusion: Chemotherapy significantly affects haemoglobin levels and platelet count in both breast and colorectal cancer patients.

Keywords: Cervical Cancer, HPV, Triage Test

Introduction

Background to the Problem

Cancer is regarded as a disease where cells transform abnormally and proliferate uncontrollably, due to genetic and epigenetic factors [1]. A comprehensive analysis by the International Agency for Research on Cancer (IARC), revealed that breast and colorectal cancers are among the most commonly diagnosed cancers within South America [2].

Across the South American region in 2022, there were 1,155,885 new cases of cancer for both sexes. From these cases, it was estimated that 165,427 were newly diagnosed breast cancer patients and within that cohort, an estimated 43,253 died. Notably, all newly diagnosed breast cancer patients were reported as females [3]. In Guyana, the burden of cancer was as significant as in more developed countries. Estimates from 2022 indicated that there were 1,225 new cancer cases that year, which included 229 breast cancer cases; 67 of which resulted in death [4].

Another important cause of cancer-related death is colorectal cancer. In 2022, it was reported that across South America, there were 112,317 new colorectal cases that year (56,725 males and 55,592 females) and within that cohort, an estimated 55,543 died [3]. However, in Guyana, the clinical picture was less stark. In 2022, there was an estimate of 79 new cases of colorectal cancer and 46 deaths [4]. Nonetheless, chemotherapy is an indispensable approach for managing patients with breast and colorectal cancer and has significantly improved the overall patient survival rate [5,6].

Despite its efficacy, chemotherapy has been directly linked to a range of complications that can adversely impact a patients' well-being; where myelosuppression is one such complication [7]. Chemotherapy-induced myelosuppression is characterized by diminished number of bone marrow progenitor cells, and abnormal complete blood cell count results [5-7]. Chemotherapy-induced thrombocytopenia (CIT) is a potentially serious complication where there is an abnormally low Plt count.

Cytotoxic chemotherapy agents would limit the production of megakaryocyte progenitors which leads to decreased thrombocyte production and subsequently causes CIT [8-10]. CIT can cause delays, reductions, or discontinuation of chemotherapy doses leading to poor patient outcomes. Moreover, CIT raises the risk of significant bleeding events, possibly resulting in hospitalization [10]. With regards to chemotherapy-induced anaemia (CIA), this is the most common haematological abnormality in cancer patients undergoing aggressive chemotherapy [12]. It results from the invasion of normal tissue by cancer leading to blood loss, bone marrow infiltration with disruption of erythropoiesis, and functional iron deficiency due to inflammation [11,12]. Beyond the physiological aspects, CIA extends its impact to the quality of the patient's life.

Common clinical presentations such as tiredness, dyspnoea, vertigo, anorexia, and poor concentration are some of the challenges the patient may experience [12]. Although chemotherapy is a mainstay of cancer treatment, it is important that the full spectrum of the chemotherapeutic effects on cancer patients receiving treatment is taken into consideration when managing these patients. Holistically, this should involve consistent monitoring

of a patient's haematological profile; particularly their Hb levels and Plt counts [13].

Problem

Although the chemotherapeutic regimens used at GPHC effectively treat breast and colorectal cancer, there are no published studies on the monitoring of markers associated with myelosuppression (i.e., Hb level and Plt count) to the use of current regimens.

Purpose and Significance of the Research

The purpose of this research is to assess the impact of chemotherapy on Plt count and haemoglobin levels in breast cancer and colorectal cancer patients, pre-and post-treatment. Significantly, this information can be used to guide physicians when they are modifying patient treatment regimens or considering the use of newer chemotherapeutic agents [14-18].

Research Questions

1. What is the mean Hb level among pre- and post-chemotherapy patients with breast and colorectal cancer?
2. What is the mean Plt count among pre- and post-chemotherapy patients with breast and colorectal cancer?
3. Does staging determine the extent to which mean Hb level and mean Plt count vary among breast and colorectal cancer patients?

Method

Study Design

This retrospective study analyzed the effects of chemotherapy on haemoglobin levels and platelet counts in breast and colorectal cancer patients. The study period spanned 1st January 2020 to 31st December 2023, during which relevant patient data were collected. The data were accessed for research purposes on 15th January 2024. All patient records were anonymized prior to analysis. The authors did not have access to personally identifiable information during or after data collection; only de-identified data were used for statistical analysis [19-24].

Setting

The study was conducted at GPHC, following approval from the Ministry of Health Institutional Review Board (IRB) on April 3, 2024, and subsequent approval from GPHC on June 21, 2024. Permission to access patient records was granted by the clinical coordinator of the oncology clinic. Pages 49-51 within the manuscript comprise the IRB memo and approval letter from Guyana's Ministry of Health IRB (FWA00030719). The IRB approval protocol is W#012/2024. These and other pertinent information are available under the supporting information heading within the manuscript [25-30].

Participants

Inclusion Criteria: Patients aged 18-65 years diagnosed with breast cancer, triple-negative breast cancer, or colorectal cancer confirmed through histopathological examination. Patients who received chemotherapy with specific agents were included: adriamycin, cyclophosphamide, paclitaxel, cisplatin, carboplatin (for breast cancer), FOLFOX and capecitabine (for colorectal cancer).

Exclusion Criteria: Patients were excluded if they were under 18 years old, deceased, had lab results from non-GPHC laboratories, were immunocompromised (e.g., HIV-positive), were on blood thinners (e.g., Warfarin), had a history of completed chemotherapy with cancer recurrence, had known haematological disorders (e.g., Thalassemia), had incomplete sociodemographic or laboratory data, or had comorbidities such as HBV, HCV, or Tuberculosis [31-35].

Selection of Participant

A total of 220 breast cancer medical records and 30 colorectal cancer medical records were selected using purposive sampling. This method allowed for the intentional selection of medical records that met the study's inclusion criteria [36-40].

Variables

• **Haematological outcomes (quantitative, dependent):** i) Hb Level ii) Plt Count

• **Predictors (qualitative, independent):** i) Type of Cancer ii) Stage of Cancer iii) Treatment Regimen

• **Confounding factors (qualitative):** i) Age ii) Gender iii) Ethnicity.

Data Sources/Measurement

Data were extracted from patient medical records, including demographic details (age, sex, ethnicity), cancer type and stage, tumour grade, treatment regimens, and haematological parameters [41-45].

Bias

The researchers addressed bias by catering to an extensive and diverse sample population that represented various demographics (such as every ethnicity, gender and stage of cancer that was evident among patient records). There was an inclusion and exclusion criteria, and also a rationale for the purposive sampling of these patient records. Multiple linear regression was utilised to control for potential confounding variables (such as gender and ethnicity).

Results

Participants

Table 1: Participants of the Breast Cancer Study Population.

Stage of Study	Breast Cancer Patients
Potentially Eligible	363
Examined for Eligibility	250
Confirmed Eligible	220
Included in the Study	220
Analyzed	220

Table 1 outlines the participants in the breast cancer study population. Initially, 363 breast cancer patient records were identified for this study. After reviewing 250 patient records, 220 were

Study Size

The sample size was determined based on the availability of eligible patients within the study period. The researchers were able to obtain a sample of 220 BC patient records and 30 CRC patient records [46-50].

Statistical Methods

Descriptive Statistics

The means, standard deviations, and standard errors, were calculated for haemoglobin level and platelet count before and after chemotherapy. These statistics provided an overview of the central tendency and variability of the data [51-55].

Paired Sample T-Tests

Paired Sample t-tests were conducted to assess whether there was a statistically significant difference between mean pre-chemotherapy and mean post-chemotherapy values. A p-value < 0.05 was considered statistically significant [56-60].

Linear Regression

Linear regression analyses were used to explore if there was a relationship between specific subgroups and Hb level or Plt count after chemotherapy. The study population, which included both breast and colorectal cancer patients, was divided into subgroups based on factors such as cancer stage, gender, ethnicity, and chemotherapy regimen. For both CRC and BC data, multiple linear regression was used to model the relationship between Hb level after chemotherapy and the predictors (stage of cancer and the treatment regimen).

The same was conducted for Plt count after chemotherapy. Multiple linear regression was also used to model the relationship for the respective haematological parameters after chemotherapy and the predictors (gender and ethnicity) for CRC records, which included both males and females. However, for BC records, a simple linear regression was done to model the relationship between ethnicity and the respective haematological parameters after chemotherapy; since all BC data comprised female patients [61-65].

found to meet the study's eligibility criteria while 30 patient records were excluded due to being immunocompromised or having incomplete laboratory data.

Table 2: Participants of the Colorectal Cancer Study Population.

Stage of Study	Colorectal Cancer Patients
Potentially Eligible	50
Examined for Eligibility	35
Confirmed Eligible	30
Included in the Study	30
Analyzed	30

Table 2 outlines the participants in the breast colorectal cancer study population. Initially, 50 colorectal cancer patient records were identified for this study. After reviewing 35 patient records,

30 were found to meet the study's eligibility criteria while 5 patient records were excluded due to being immunocompromised or having incomplete laboratory data.

Descriptive Data

Table 3: Demographic and Clinical Characteristics of the Breast Cancer Study Population.

Variables	Categories	Frequency (n=220)	Percentage (100%)	Mean $\pm$ SD
Age Gender Ethnicity	18-65	220	100	52.51 $\pm$ 9.0
	Female	220	100	NA
	Amerindian	14	6.4	NA
	African	80	36.4	NA
	East Indian	83	37.7	NA
	Portuguese	-	-	NA
	Chinese	1	0.5	NA
	Mixed	42	19.1	NA
Diagnosis	Invasive Ductal Carcinoma	205	93.2	NA
	Invasive Lobular Carcinoma	5	2.3	NA
	Invasive Medullary Carcinoma	2	0.9	NA
	Infiltrative Ductal Carcinoma	5	2.3	NA
	Invasive Nodular Carcinoma	1	0.5	NA
Stage of the Cancer	Tubular Carcinoma	1	0.5	NA
	Mixed Type Carcinoma	1	0.5	NA
	I	31	14.1	NA
	II	121	55.0	NA
	III	51	23.2	NA
	IV	17	7.7	NA
Treatment Regimen	Adriamycin, Cyclophosphamide, Flush	173	78.6	NA
	Paclitaxel, Flush	10	4.5	NA
	Cyclophosphamide, Docetaxel, Flush	2	0.9	NA
	Adriamycin, Cyclophosphamide, Paclitaxel, Flush	18	8.2	NA
	Cyclophosphamide, Docetaxel, Adriamycin, 5FU, Methotrexate, Flush	3	1.4	NA

	Cisplatin, Docetaxel, Paclitaxel, Flush	1	0.5	NA
	Docetaxel, Carboplatin, Flush	4	1.8	NA
	Adriamycin, Cyclophosphamide, Paclitaxel, Docetaxel, Flush	2	0.9	NA
	Docetaxel, Gemcitabine, Flush	3	1.4	NA
	Cyclophosphamide, Paclitaxel, Methotrexate, Flush	2	0.9	NA
	Carboplatin, Paclitaxel, Flush	2	0.9	NA

Table 3 provides an overview of the demographic and clinical characteristics of the breast cancer study population. The study included 220 female breast cancer patients, with a mean age of 52.51

± 9.0 years. Among the patients, East Indians were the most prevalent group at 37.7%, followed closely by Africans at 36.4%.

The most prevalent breast cancer was that of invasive ductal carcinoma (93.2%) followed by invasive lobular carcinoma (2.3%) and infiltrative ductal carcinoma (2.3%). Most patients had stage II (55.0%) breast cancer. The most common treatment regimen was adriamycin, cyclophosphamide and flush (78.6 %).

Table 4: Demographic and Clinical Characteristics of the Colorectal Cancer Study Population.

Variables	Categories	Frequency (n=30)	Percentage (100%)	Mean ± SD
Age	18-65	30	100.0	54.20 ± 9.18
Gender	Female	18	60.0	NA
	Male	12	40.0	NA
Ethnicity	African	15	50.0	NA
	East Indian	12	40.0	NA
	Mixed	3	10.0	NA
Diagnosis	Colon Cancer	19	63.3	NA
	Rectal Cancer	11	36.7	NA
Stage of the Cancer	II	16	53.3	NA
	III	9	30.0	NA
	IV	5	16.7	NA
Treatment Regimen	FOLFOX 6, Flush	15	50	NA
	Capecitabine	2	6.7	NA
	FOLFOX 6,			
Capecitabine, Flush	13	43.3	NA	

Table 4 provides an overview of the demographic and clinical characteristics of the colorectal cancer study population. The study included 30 colorectal cancer patients with a mean age of 54.20 ± 9.18 years. Among the patients, Africans (50.0%) were the most prevalent group, followed closely by East Indians

(40.0%). The most prevalent colorectal cancer was that of colon cancer (63.3%) followed by rectal cancer (36.7%). Most patients had stage II (53.3%) colorectal cancer. The most common treatment regimen was FOLFOX 6 and flush (50.0%).

Main Results

Table 5: Mean Pre- and Post- Chemotherapy Values for the Breast Cancer Study Population.

Haematological Parameters	Pre- Chemotherapy Mean ± SD	Post- Chemotherapy Mean ± SD	P-value
Haemoglobin Level	12.21 ± 1.27	11.50 ± 1.32	0.000*
Platelet Count	320.56 ± 118.42	288.18 ± 123.37	0.000*

* Statistically significant at p < 0.05.

Table 5 summarises the mean pre- and post- chemotherapy values for the breast cancer study population. The mean pre- chemotherapy Hb level for breast cancer patients was 12.21 ± 1.27 g/dl, and the post- chemotherapy Hb level for breast cancer patients was 11.50 ± 1.32 g/dl, reflecting a mean difference of 0.71

g/dl. The mean pre- chemotherapy Plt count for breast cancer patients was $320.56 \pm 118.42 \times 10^9/L$, and the post- chemotherapy Plt count for breast cancer patients was $288.18 \pm 123.37 \times 10^9/L$, reflecting a mean difference of $32.39 \times 10^9/L$.

Table 6: Mean Pre- and Post- Chemotherapy Values for the Colorectal Cancer Study Population.

Haematological Parameters	Pre- Chemotherapy Mean $\pm$ SD	Post- Chemotherapy Mean $\pm$ SD	P-value
Haemoglobin Level	12.52 ± 1.31	11.71 ± 1.17	0.003*
Platelet Count	276.30 ± 127.58	202.87 ± 67.71	0.000*

Table 6 summarises the mean pre- and post- chemotherapy values for the colorectal cancer study population. The mean pre- chemotherapy Hb level for breast cancer patients was 12.52 ± 1.31 g/dl, and the post- chemotherapy Hb level for breast cancer patients was 11.71 ± 1.17 g/dl, reflecting a mean difference of

0.81 g/dl. The mean pre- chemotherapy Plt count for breast cancer patients was $276.30 \pm 127.58 \times 10^9/L$ and the post- chemotherapy Plt count for breast cancer patients was $202.87 \pm 67.71 \times 10^9/L$, reflecting a mean difference of $73.43 \times 10^9/L$.

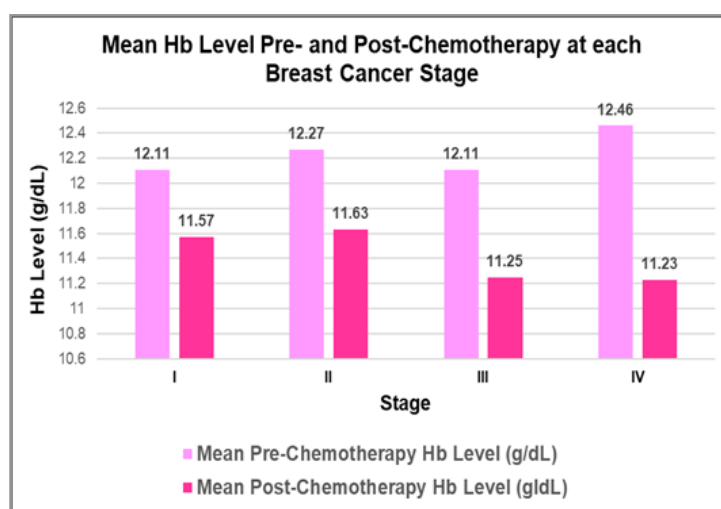


Figure1: Mean Hb Level Before and After Chemotherapy for the Breast Cancer Stages.

Figure 1 illustrates the mean Hb count pre- and post- chemotherapy for breast cancer stages. There were slight variations of the mean Hb levels at each stage. The mean differences for stages I-IV were 0.55 g/dl, 0.64 g/dl, 0.86 g/dl and 1.23 g/dl respectively.

These results indicate that the decrease in Hb levels post chemotherapy progressively increased with advancing cancer stages, with Stage IV showing the greatest reduction.

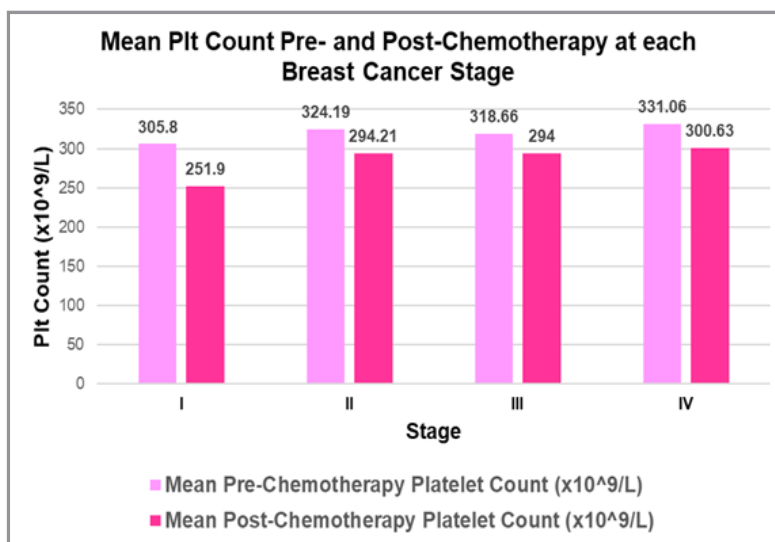


Figure 2: Mean Plt Count Before and After Chemotherapy for the Breast Cancer Stages.

Figure 2 illustrates the mean Plt count pre- and post- chemotherapy for breast cancer stages. There were noticeable variations in the mean Plt counts at each cancer stage. The mean differences for stages I to IV were $53.90 \times 10^9/L$, $29.98 \times 10^9/L$, $24.66 \times$

$10^9/L$ and $30.44 \times 10^9/L$ respectively. These results indicated that the reduction in Plt count post-chemotherapy varied across stages, with Stage I showing the largest decrease and more moderate changes observed in later stages.

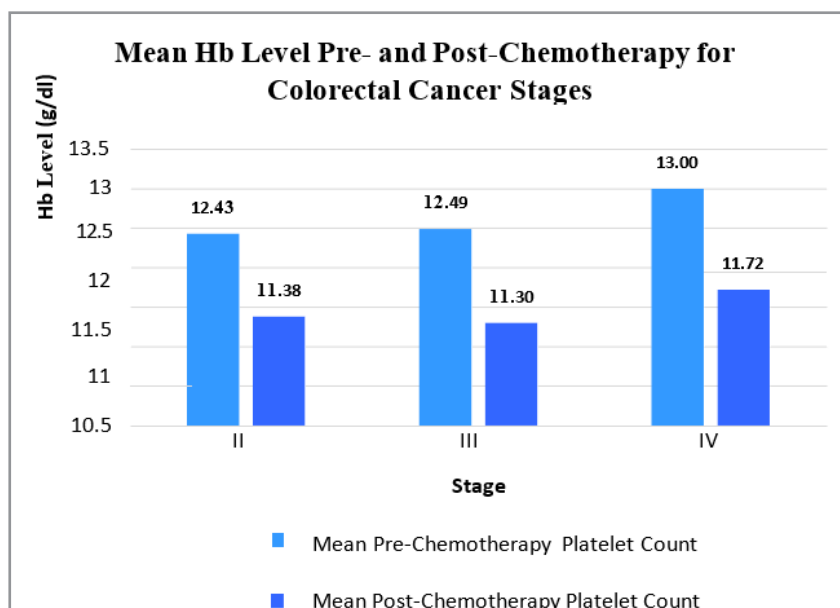


Figure 3: Mean Hb Level Before and After Chemotherapy for the Colorectal Cancer Stages

Figure 3 illustrates the mean Hb count pre- and post- chemotherapy for colorectal cancer stages. There were slight variations of the mean Hb levels at each stage. The mean differences for stage II to IV were 1.05 g/dl, 1.19 g/dl and 1.28 g/dl respectively.

These results indicate that the decrease in Hb levels after chemotherapy progressively increased with advancing cancer stages, with Stage IV showing the greatest reduction.

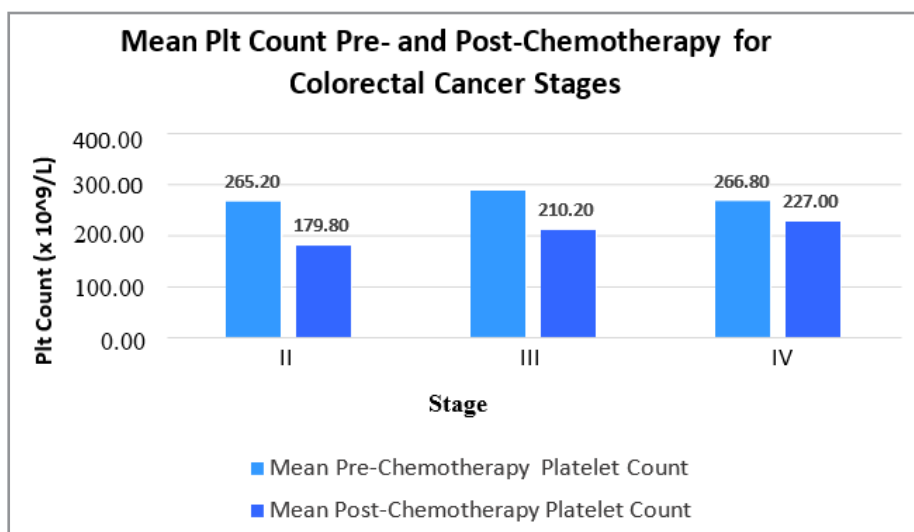


Figure 4: Mean Plt Count Before and After Chemotherapy for the Colorectal Cancer Stages.

Figure 4 illustrates the mean Plt count pre- and post- chemotherapy for colorectal cancer stages. There were noticeable variations in the mean Plt counts at each cancer stage. The mean differences for stage II to III were $85.40 \times 10^9/L$, $76.67 \times 10^9/L$ and $39.80 \times 10^9/L$ respectively. These results indicate that the reduction in platelet count after chemotherapy varied across the cancer stages, with a more pronounced decrease in earlier stages (Stage II and III) compared to Stage IV.

From a sample population of breast cancer patients ($n= 220$), there was a statistically significant difference in both the mean Hb level and Plt count after chemotherapy ($p < 0.001$ and $t > 1.972$ for both parameters) at the 95% CI. This indicated that chemotherapy had a significant impact (decrease) on both of these parameters.

Particularly, the mean difference between Hb levels before and after chemotherapy was 0.71182 g/dl, while the mean difference between platelet counts before and after chemotherapy was $32.38636 \times 10^9/L$. These findings aligned with the literature,

Discussion

Breast Cancer

which corroborated a marked reduction in those haematological parameters due to bone marrow suppression and impaired haematopoiesis [66-70].

However, there were statistically significant ($p < 0.001$) moderate and strong positive correlations ($R = 0.46$ for Hb level, $R = 0.70$ for Plt count) for the respective parameters, which suggested that patients with higher Hb and Plt values before chemotherapy, were likely to have higher values after chemotherapy [71]. Upon further analyses, it was found that the stage of breast cancer in tandem with the treatment regimen for chemotherapy, had a weak positive ($R = 0.120$) correlation; where merely 1.4% of the variance ($R^2 = 0.014$) in Hb level after chemotherapy, was explained by the stage of breast cancer (i.e., stages I-IV) and the treatment regimen (i.e., adriamycin and cyclophosphamide which were predominantly administered for all stages through dosages based on body surface area). Notably, this weak positive correlation was not significant ($p > 0.05$); which reinforced that these predictors were not a good fit for the data [72,73].

Likewise, it was found that the stage of breast cancer and treatment regimen for chemotherapy collectively had a weak positive ($R = 0.110$) correlation where merely 1.2 % of the variance ($R^2 = 0.012$) in Plt count after chemotherapy, was explained by the stage of breast cancer and the treatment regimen [74-80]. This weak positive correlation was also not significant ($p > 0.05$). To elaborate, the ethnicity of the patients was also analyzed against the values after chemotherapy, for these haematological parameters. It was found that ethnicity (African, East Indian, Mixed, Amerindian and Chinese) had a weak positive ($R = 0.024$) correlation where merely 0.1% of the variance ($R^2 = 0.001$) in Hb level after chemotherapy, was explained by the same. This weak positive correlation was not significant ($p > 0.05$) [81,82].

As for Plt count after chemotherapy, it was that ethnicity also had a weak positive ($R = 0.018$) correlation where 0.0 % (none) of the variance in Plt count after chemotherapy, was explained by the same. Such observations reflected the literature which indicated that factors beyond cancer stage and treatment protocol, such as genetic predisposition, nutrition and underlying comorbidities may play a more significant role in determining the extent of hematologic changes [83-90].

Colorectal Cancer

Meanwhile, from a sample population of colorectal cancer patients ($n = 30$), there was a statistically significant difference in both the mean Hb level and Plt count after chemotherapy ($p < 0.05$ and $t > 1.972$ for both parameters) at the 95% CI.

This indicated that chemotherapy significantly impacted (decrease) both of these parameters. Particularly, the mean difference between Hb level before and after chemotherapy was 0.81 g/dl, while the mean difference between Plt count before and after chemotherapy was $73.43 \times 10^9/L$. As mentioned for the BC findings, these findings for CRC were also consistent with the literature [91-95].

Nonetheless, Hb levels showed a statistically significant ($p < 0.05$), moderately positive correlation ($R = 0.40$) before and after chemotherapy; whereas, the Plt count showed a statistically significant ($p < 0.001$) strongly positive correlation ($R = 0.68$) before

and after chemotherapy [96,97].

Upon further analyses, it was found that the stage of colorectal cancer and treatment regimen for chemotherapy collectively had a very weak positive ($R = 0.104$) correlation where merely 1.1% of the variance ($R^2 = 0.011$) in Hb level after chemotherapy, was explained by the stage of colorectal cancer (i.e., stages II-IV) and the treatment regimen (i.e., FOLFOX 6 and capecitabine were predominately administered for all stages through dosages based on body surface area). Notably, the weak positive was not significant ($p > 0.05$), which reinforced that these predictors were not a good fit for the data [98,99].

Likewise, it was found that the stage of colorectal cancer and treatment regimen for chemotherapy collectively had a very weak positive ($R = 0.086$) correlation where merely 0.7% of the variance ($R^2 = 0.007$) in Plt count after chemotherapy, was explained by the stage of colorectal cancer and the treatment regimen [100, 101].

The weak positive correlation was also not significant ($p > 0.05$). To elaborate, the ethnicity of the patients was also analysed against the values after chemotherapy, for these haematological parameters. It was found that ethnicity (African, East Indian, Mixed) had a weak positive ($R = 0.104$) correlation where merely 1.1% of the variance ($R^2 = 0.011$) in Hb level after chemotherapy, was explained by the same.

This weak positive correlation was not significant ($p > 0.05$). As for the Plt count after chemotherapy, it was found that ethnicity also had a weak positive ($R = 0.148$) correlation where 2.2% of the variance ($R^2 = 0.022$) in Plt count after chemotherapy, was explained by the same [102-105].

Ultimately, while chemotherapy in general impacts Hb levels and Plt counts, the variability in Hb levels and Plt counts post-chemotherapy was not well explained by the stage of cancer, treatment regimen or ethnicity since they were not significant predictors. These inferences highlight the need for further research with larger sample sizes and additional predictors which may better explain the observed changes in Hb level and Plt count [106,107].

Limitations

- Some patient data such as genetic predisposition, lifestyle factors such as smoking status, diet and comorbidities were not documented within their files.
- Some patients were inactive due to migration, death and treatment at secondary institutions.
- Patient charts were neither organised nor filled according to standard protocols.
- All charts were manually filled and the doctor's handwriting was not always legible.

Generalisability

Sample Size

The sample size of 220 for BC patients was likely representative of the broader population of breast cancer patients within Guyana. Conversely, the study only included 30 CRC patients. This was a small sample size which limited the generalizability of the results to the broader population of CRC patients within Guy-

ana. Thus, the findings from this small cohort may not accurately represent the effects of chemotherapy on haemoglobin level and platelet count for CRC patients within Guyana [108-110].

Chemotherapy Regimens

The chemotherapy regimens used in the study were specific to GPHC and may or may not be the same to those used at other hospitals. Particularly, GPHC's BC patients were generally administered with adriamycin and cyclophosphamide, while their CRC patients were generally administered with FOLFOX 6 and capecitabine [111-115].

Cancer Type

The haematological results from CRC patients were not generalizable to BC patients and vice versa. Thus, the effects of chemotherapy on haemoglobin level and platelet count differed between these two groups [116, 117].

Conclusions and Recommendations

It can be concluded that for both breast and colorectal cancer patients, there was a statistically significant difference between the mean Hb level and Plt count before and after chemotherapy. Some key recommendations posited to the oncology clinic (which they have started to embark on) include timely supportive therapies and transfusion guidelines for patients with a lower-than-normal Hb level and Plt count. For instance, nutritional support interventions may enhance blood cell production through supplements such as iron, vitamin B12, vitamin C, vitamin K and folate. To add, prescriptive erythropoiesis-stimulating agents (ESAs) and/or thrombopoietin receptor agonists (TPO-RAs) can also be utilised in a timely manner to stimulate erythrocyte and thrombocyte production respectively [118-120].

Acknowledgements

The authors gratefully acknowledge their supervisors—Mr. Paul Cheddie, Dr. Latoya Gooding, and Ms. Audrey Anderson for their guidance, support, and encouragement throughout this project. The authors also extend special thanks to Professor Rajini Kurup for her valuable advice and contributions, which greatly enhanced the quality of this research. Finally, the authors thank the College of Medical Sciences for providing a supportive academic environment [121-124].

References

1. Brown, J., Amend, S., Austin, R., Gatenby, R., Hammarlund, E., & Pienta, K. (2023). Updating the definition of cancer. *Molecular Cancer Research*, 21(11), 1142–1147. <https://doi.org/10.1158/1541-7786.MCR-22-0781>
2. International Agency for Research on Cancer. (2016, September). Cancer in Central and South America – A comprehensive analysis (pp. 1–2). World Health Organization, IARC. https://www.iarc.who.int/wp-content/uploads/2018/07/pr248_E.pdf
3. Ferlay, J., Ervik, M., Lam, F., Laversanne, M., Colombet, M., Mery, L., et al. (2024, January). South America – Factsheet. International Agency for Research on Cancer. <https://gco.iarc.who.int/media/globocan/factsheets/populations/931-south-america-fact-sheet.pdf>
4. Katzung, B. G. (2018). Basic & clinical pharmacology (14th ed.). McGraw-Hill Education.
5. Katta, B., Vijayakumar, C., Dutta, S., Dubashi, B., & Prasad, V. (2023, April 29). The incidence and severity of patient-reported side effects of chemotherapy in routine clinical care: A prospective observational study. *Cureus*, 15(4). <https://doi.org/10.7759/cureus.38365>
6. Epstein, R. S., Basu Roy, U. K., Aapro, M., Salimi, T., Moran, D., Krenitsky, J., et al. (2021, February). Cancer patients' perspectives and experiences of chemotherapy-induced myelosuppression and its impact on daily life. *Patient Preference and Adherence*, 15, 453–465. <https://doi.org/10.2147/PPA.S293160>
7. Gao, A., Zhang, L., & Zhong, D. (2023, January 25). Chemotherapy-induced thrombocytopenia: Literature review. *Discover Oncology*, 14(1). <https://doi.org/10.1007/s12672-023-00573-2>
8. Sundarmurthy, D., R, J., & C, L. (2017). Effect of Carica papaya leaf extract on platelet count in chemotherapy-induced thrombocytopenic patients: A preliminary study. *National Journal of Physiology, Pharmacy and Pharmacology*, 7(6), 1. <http://www.njppp.com/fulltext/28-1486322158.pdf>
9. Weycker, D., Hatfield, M., Grossman, A., Hanau, A., Lonshteyn, A., Sharma, A., et al. (2019, February 14). Risk and consequences of chemotherapy-induced thrombocytopenia in US clinical practice. *BMC Cancer*, 19(1). <https://doi.org/10.1186/s12885-019-5354-5>
10. Abdel-Razeq, H., & Hashem, H. (2020, January). Recent update in the pathogenesis and treatment of chemotherapy and cancer-induced anaemia. *Critical Reviews in Oncology/Hematology*, 145, 102837. <https://doi.org/10.1016/j.critrev-onc.2019.102837>
11. Bryer, E., & Henry, D. (2018). Chemotherapy-induced anemia: Etiology, pathophysiology, and implications for contemporary practice. *International Journal of Clinical Transfusion Medicine*. <https://www.dovepress.com/chemotherapy-induced-anemia-etiology-pathophysiology-and-implications-peer-reviewed-fulltext-article-IJCTM>
12. Chandra, S., & Handojo, D. (2021, April 1). The effects of cyclophosphamide, adriamycin and 5-fluorouracil chemotherapy on blood cells and cardiac hemodynamics in breast carcinoma patients: A case study at Dr. Kariadi General Hospital, Semarang, Indonesia. *Bali Medical Journal*, 10(1), 111–118. <https://doi.org/10.15562/bmj.v10i1.2134>
13. Tecza, K., Pamula-Pilat, J., Lanuszevska, J., Butkiewicz, D., & Grzybowska, E. (2018, January 10). Pharmacogenetics of toxicity of 5-fluorouracil, doxorubicin and cyclophosphamide chemotherapy in breast cancer patients. *Oncotarget*, 9(10), 9114–9136. <https://doi.org/10.18632/oncotarget.24067>
14. Aynalem, M., Adem, N., Wendesson, F., Misganaw, B., Mintesnot, S., Godo, N., et al. (2022, August 8). Hematological abnormalities before and after initiation of cancer treatment among breast cancer patients attending at the University of Gondar Comprehensive Specialized Hospital Cancer Treatment Center. *PLOS ONE*, 17(8), e0271895. <https://doi.org/10.1371/journal.pone.0271895>
15. Epstein, R. S., Aapro, M. S., Basu Roy, U. K., Salimi, T., Krenitsky, J., Leone-Perkins, M. L., et al. (2020, July 8). Patient burden and real-world management of chemotherapy-induced myelosuppression: Results from an online survey of patients with solid tumors. *Advances in Therapy*, 37(8), 3606–3618. <https://doi.org/10.1007/s12325-020-01377-y>

16. Kashyap, D., Pal, D., Sharma, R., Garg, V. K., Goel, N., Koundal, D., et al. (2022, April 18). Global increase in breast cancer incidence: Risk factors and preventive measures. *BioMed Research International*, 2022, 1–16. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9038417/>
17. Wirtz, P., & Baumann, F. T. (2018). Physical activity, exercise and breast cancer – What is the evidence for rehabilitation, aftercare, and survival? A review. *Breast Care*, 13(2), 93–101. <https://doi.org/10.1159/000488086>
18. Schmitt, M., & Greten, F. R. (2021, October 1). The inflammatory pathogenesis of colorectal cancer. *Nature Reviews Immunology*, 21(10), 653–667. <https://doi.org/10.1038/s41577-021-00534-x>
19. World Health Organization. (2023). Colorectal cancer. <https://www.who.int/news-room/fact-sheets/detail/colorectal-cancer>
20. Stefani, C., Miricescu, D., Stanescu-Spinu, I. I., Nica, R. I., Greabu, M., Totan, A. R., et al. (2021, September 23). Growth factors, PI3K/AKT/mTOR and MAPK signaling pathways in colorectal cancer pathogenesis: Where are we now? *International Journal of Molecular Sciences*, 22(19), 10260. <https://doi.org/10.3390/ijms221910260>
21. Sökmen, F., Kasapoğlu, B., Yozgat, A., & Engin, H. (2019). Assessment of hematological parameters before and after adjuvant chemotherapy in patients with colorectal cancer. *Acta Oncologica Turcica*, 52(3), 405–409.
22. Johnson-Arbor, K., & Dubey, R. (2019). Doxorubicin. StatPearls Publishing. <https://www.ncbi.nlm.nih.gov/books/NBK459232/>
23. World Health Organization. (2019). Cancer. World Health Organization. https://www.who.int/health-topics/cancer#tab=tab_1
24. Barnett, S., Kong, J., Makin, G., & Veal, G. J. (2020, June 24). Over a decade of experience with carboplatin therapeutic drug monitoring in a childhood cancer setting in the United Kingdom. *British Journal of Clinical Pharmacology*, 87(2), 256–262. <https://doi.org/10.1111/bcp.14389>
25. Nunes, M., Duarte, D., Vale, N., & Ricardo, S. (2022, December 21). The antineoplastic effect of carboplatin is potentiated by combination with pitavastatin or metformin in a chemoresistant high-grade serous carcinoma cell line. *International Journal of Molecular Sciences*, 24(1), 97. <https://doi.org/10.3390/ijms24010097>
26. Szefer, B., Czeleń, P., & Krawczyk, P. (2021, March 31). The affinity of carboplatin to B-vitamins and nucleobases. *International Journal of Molecular Sciences*, 22(7), 3634. <https://doi.org/10.3390/ijms22073634>
27. Amjad, M. T., Kasi, A., & Chidharla, A. (2023). Cancer chemotherapy. In StatPearls. StatPearls Publishing. <https://www.ncbi.nlm.nih.gov/books/NBK564367/>
28. Gold, J. M., & Raja, A. (2020). Cisplatin (Cisplatinum). In StatPearls. StatPearls Publishing. <https://www.ncbi.nlm.nih.gov/books/NBK547695/>
29. Ogino, M. H., & Tadi, P. (2020). Cyclophosphamide. In StatPearls. StatPearls Publishing. <https://www.ncbi.nlm.nih.gov/books/NBK553087/>
30. Halle, J. L., Counts, B. R., Paez, H. G., Baumfalk, D. R., Zhang, Q., Mohamed, J. S., et al. (2023, August 1). Recovery from FOLFOX chemotherapy-induced systemic and skeletal muscle metabolic dysfunction in mice. *American Journal of Physiology-Endocrinology and Metabolism*, 325(2), E132–E151. <https://pubmed.ncbi.nlm.nih.gov/37378624/>
31. Martínez-Bernal, G., Martínez-Pérez, J., & Valladares-Ayerbes, M. (2022). A roadmap for medical treatment of metastatic CRC. In Elsevier eBooks (pp. 365–379). <https://doi.org/10.1016/B978-0-12-824170-6.00025-0> (or use publisher URL if DOI unavailable)
32. Ahmed, M. H., Ghatge, M. S., & Safo, M. K. (2020). Haemoglobin: Structure, function and allostery. *Subcellular Biochemistry*, 94, 345–382. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7370311/>
33. Dybas, J., Bokamper, M. J., Marzec, K. M., & Mak, P. J. (2020, October). Probing the structure-function relationship of haemoglobin in living human red blood cells. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, 239, 118530. <https://doi.org/10.1016/j.saa.2020.118530>
34. Farrar, M. C., & Jacobs, T. F. (2021). Paclitaxel. In StatPearls. StatPearls Publishing. <https://www.ncbi.nlm.nih.gov/books/NBK536917/>
35. Mahajan, D., Aashna, K., Koul, K., & Jandial, A. (2019, August 15). Platelet count correlation: Automated versus manual on peripheral smear. *Indian Journal of Pathology and Oncology*, 6(3), 381–387. <https://doi.org/10.18231/ijpo.2019>
36. Jain, D. K. (2020, September 24). Comparison of platelet count by manual and automated method. *International Journal of Research in Medical Sciences*, 8(10), 3523. <https://doi.org/10.18203/2320-6012.ijrms20204361>
37. Centers for Disease Control and Prevention. (2023). What is breast cancer? Centers for Disease Control and Prevention. https://www.cdc.gov/cancer/breast/basic_info/what-is-breast-cancer.htm
38. Faramarzi, A., Golestan Jahromi, M., Ashourzadeh, S., & Jalilian, N. (2021). Metastatic and pathophysiological characteristics of breast cancer with emphasis on hereditary factors. *Central Asian Journal of Medical and Pharmaceutical Sciences Innovation*, 3, 104–113. https://www.cajmpsi.com/article_131715_3a202dc3616690eea14db4905ccd97df.pdf
39. Rebbeck, T. R., Mitra, N., Wan, F., Sinilnikova, O. M., Healey, S., McGuffog, L., et al. (2015, April 7). Association of type and location of BRCA1 and BRCA2 mutations with risk of breast and ovarian cancer. *JAMA*, 313(13), 1347–1361. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4537700/>
40. Talhouet, S. D., Peron, J., Vuilleumier, A., Friedlaender, A., Viassolo, V., Ayme, A., et al. (2020, April 27). Clinical outcome of breast cancer in carriers of BRCA1 and BRCA2 mutations according to molecular subtypes. *Scientific Reports*, 10(1), 1–10. <https://doi.org/10.1038/s41598-020-63759-4>
41. Mylavarapu, S., Das, A., & Roy, M. (2018, February 5). Role of BRCA mutations in the modulation of response to platinum therapy. *Frontiers in Oncology*, 8, Article 16. <https://doi.org/10.3389/fonc.2018.00016>
42. Huszno, J., Kołosza, Z., & Grzybowska, E. (2018, November 28). BRCA1 mutation in breast cancer patients: Analysis of prognostic factors and survival. *Oncology Letters*, 17(2), 1986–1995. <https://doi.org/10.3892/ol.2018.9753>
43. Feng, Y., Spezia, M., Huang, S., Yuan, C., Zeng, Z., Zhang, L., et al. (2018, June). Breast cancer development and progression: Risk factors, cancer stem cells, signalling path-

- ways, genomics, and molecular pathogenesis. *Genes & Diseases*, 5(2), 77–106. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6147049/>
44. Hinyard, L., Wirth, L. S., Clancy, J. M., & Schwartz, T. (2017, April). The effect of marital status on breast cancer-related outcomes in women under 65: A SEER database analysis. *The Breast*, 32, 137–143. <https://doi.org/10.1016/j.breast.2017.01.017>
 45. Picon-Ruiz, M., Morata-Tarifa, C., Valle-Goffin, J. J., Friedman, E. R., & Slingerland, J. M. (2017, August 1). Obesity and adverse breast cancer risk and outcome: Mechanistic insights and strategies for intervention. *CA: A Cancer Journal for Clinicians*, 67(5), 378–397. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5591063/>
 46. Suzuki, Y., Tsunoda, H., Kimura, T., & Yamauchi, H. (2017, August 31). BMI change and abdominal circumference are risk factors for breast cancer, even in Asian women. *Breast Cancer Research and Treatment*, 166(3), 919–925. <https://doi.org/10.1007/s10549-017-4463-3>
 47. Recalde, M., Davila-Batista, V., Díaz, Y., Leitzmann, M., Romieu, I., Freisling, H., et al. (2021, January 14). Body mass index and waist circumference in relation to the risk of 26 types of cancer: A prospective cohort study of 3.5 million adults in Spain. *BMC Medicine*, 19(1), 1–12. <https://doi.org/10.1186/s12916-020-01849-1>
 48. Niehoff, N., White, A. J., McCullough, L. E., Steck, S. E., Beyea, J., Mordukhovich, I., et al. (2017, January). Polycyclic aromatic hydrocarbons and postmenopausal breast cancer: An evaluation of effect measure modification by body mass index and weight change. *Environmental Research*, 152, 17–25. <https://doi.org/10.1016/j.envres.2016.09.031>
 49. Jones, M. E., Schoemaker, M. J., Wright, L. B., Ashworth, A., & Swerdlow, A. J. (2017, November 22). Smoking and risk of breast cancer in the Generations Study cohort. *Breast Cancer Research*, 19(1), 118. <https://doi.org/10.1186/s13058-017-0908-4>
 50. Barndahl, M., Rudolph, A., Hopper, J. L., Southey, M. C., Brooks, A., Fasching, P. A., et al. (2017, August 11). Gene-environment interactions involving functional variants: Results from the Breast Cancer Association Consortium. *International Journal of Cancer*, 141(9), 1830–1840. <https://doi.org/10.1002/ijc.30869>
 51. Insua-Rodríguez, J., & Oskarsson, T. (2016, February). The extracellular matrix in breast cancer. *Advanced Drug Delivery Reviews*, 97, 41–55. <https://doi.org/10.1016/j.addr.2015.12.017>
 52. Giuliano, A. E., Edge, S. B., & Hortobagyi, G. N. (2018, April 18). Eighth edition of the AJCC Cancer Staging Manual: Breast cancer. *Annals of Surgical Oncology*, 25(7), 1783–1785. <https://doi.org/10.1245/s10434-018-6462-6>
 53. American College of Surgeons. (n.d.). Breast cancer staging. <https://www.facs.org/for-patients/home-skills-for-patients/breast-cancer-surgery/breast-cancer-types/breast-cancer-staging/>
 54. Makki, J. (2015, January). Diversity of breast carcinoma: Histological subtypes and clinical relevance. *Clinical Medicine Insights: Pathology*, 8, 23–31. <https://doi.org/10.4137/CPath.S31563>
 55. Nascimento, R. G. do, & Otoni, K. M. (2020). Histological and molecular classification of breast cancer: What do we know? *Mastology*, 30. <https://doi.org/10.29289/2594539420202020301>
 56. Jorns, J., Muller, K., Tozbikian, G., & Rakha, E. (2023). NST (ductal). *PathologyOutlines.com*. <https://www.pathologyoutlines.com/topic/breastmalignantductalNOS.html>
 57. Reisenbichler, E. (2021). Classic. *PathologyOutlines.com*. <https://www.pathologyoutlines.com/topic/breastmalignantlobularclassic.html>
 58. Zhang, H., & Jorns, J. (2023). Metaplastic. *PathologyOutlines.com*. <https://www.pathologyoutlines.com/topic/breastmalignantmetaplastic.html>
 59. Moratti, J. (2023). Apocrine. *PathologyOutlines.com*. <https://www.pathologyoutlines.com/topic/breastmalignantapocrine.html>
 60. Shankaralingappa, S. (2023). Cribriform. *PathologyOutlines.com*. <https://www.pathologyoutlines.com/topic/breastmalignantcribriform.html>
 61. Zaha, D. C. (2014). Significance of immunohistochemistry in breast cancer. *World Journal of Clinical Oncology*, 5(3), 382–392. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4127609/>
 62. Cimino-Mathews, A. (2021, January 1). Novel uses of immunohistochemistry in breast pathology: Interpretation and pitfalls. *Modern Pathology*, 34(1), 62–77. <https://www.nature.com/articles/s41379-020-00697-3>
 63. Al-Joufi, F., Setia, A., Salem-Bekhit, M., Sahu, R., Alqahtani, F., Widyowati, R., et al. (2022, January 4). Molecular pathogenesis of colorectal cancer with an emphasis on recent advances in biomarkers, as well as nanotechnology-based diagnostic and therapeutic approaches. *Nanomaterials*, 12(1), 169. <https://doi.org/10.3390/nano12010169>
 64. Rathva, B., & Desai, S. (2020). Colorectal cancer: Etiology, pathogenesis and current treatment. *Journal of Innovations in Pharmaceutical and Biological Sciences (JIPBS)*, 7(4), 20–4.
 65. Mao, R., Krautscheid, P., Graham, R. P., Ganguly, A., Shankar, S., Ferber, M., et al. (2021, June 17). Genetic testing for inherited colorectal cancer and polyposis, 2021 revision: A technical standard of the American College of Medical Genetics and Genomics (ACMG). *Genetics in Medicine*, 23(10), 1796–1807. <https://doi.org/10.1038/s41436-021-01188-4>
 66. Grady, W. M., & Markowitz, S. D. (2014, December 10). The molecular pathogenesis of colorectal cancer and its potential application to colorectal cancer screening. *Digestive Diseases and Sciences*, 60(3), 762–772. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4779895/>
 67. Kasi, A., Handa, S., Bhatti, S., Umar, S., Bansal, A., & Sun, W. (2020, August 15). Molecular pathogenesis and classification of colorectal carcinoma. *Current Colorectal Cancer Reports*, 16(5), 97–106. <https://doi.org/10.1007/s11888-020-00528-w>
 68. Rebuzzi, F., Ulivi, P., & Tedaldi, G. (2023). Genetic predisposition to colorectal cancer: How many and which genes to test? *International Journal of Molecular Sciences*, 24(3), 2137. <https://www.mdpi.com/1422-0067/24/3/2137>
 69. Valle, L., de Voer, R. M., Goldberg, Y., Sjrursen, W., Försti, A., Ruiz-Ponte, C., et al. (2019, October). Update on genetic predisposition to colorectal cancer and polyposis.

- Molecular Aspects of Medicine, 69, 10–26. <https://doi.org/10.1016/j.mam.2019.05.002>
70. Liu, J., Xiao, Q., Xiao, J., Niu, C., Li, Y., Zhang, X., et al. (2022, January 3). Wnt/ β -catenin signalling: Function, biological mechanisms, and therapeutic opportunities. *Signal Transduction and Targeted Therapy*, 7(3), 3. <https://doi.org/10.1038/s41392-021-00831-5>
71. Giroux, V., & Rustgi, A. K. (2017, September 1). Metaplasia: Tissue injury adaptation and a precursor to the dysplasia–cancer sequence. *Nature Reviews Cancer*, 17(10), 594–604. <https://www.nature.com/articles/nrc.2017.68>
72. Tie, Y., Tang, F., Wei, Y., & Wei, X. (2022, May 18). Immunosuppressive cells in cancer: Mechanisms and potential therapeutic targets. *Journal of Hematology & Oncology*, 15(1), Article 61. <https://jhoonline.biomedcentral.com/articles/10.1186/s13045-022-01282-8>
73. Li, F., Gao, Y., Cheng, W., Su, X., & Yang, R. (2023, August 1). Gut fungal mycobiome: A significant factor of tumor occurrence and development. *Cancer Letters*, 569, 216302. <https://doi.org/10.1016/j.canlet.2023.216302>
74. Kaźmierczak-Siedlecka, K., Dvořák, A., Folwarski, M., Dąca, A., Przewłocka, K., & Makarewicz, W. (2020, May 22). Fungal gut microbiota dysbiosis and its role in colorectal, oral, and pancreatic carcinogenesis. *Cancers*, 12(5), 1326. <https://doi.org/10.3390/cancers12051326>
75. Amin, M. B., Edge, S. B., Greene, F. L., Byrd, D. R., Brookland, R. K., Washington, M. K., et al. (2017). *AJCC Cancer Staging Manual* (8th ed.). Cham: Springer International Publishing. <https://doi.org/10.1007/978-3-319-40618-3>
76. International Agency for Research on Cancer. (2019). Colorectal cancer. IARC. <https://www.ncbi.nlm.nih.gov/books/NBK553197/>
77. Davri, A., Birbas, E., Kanavos, T., Ntritsos, G., Giannakeas, N., Tzallas, T., et al. (2022, March 29). Deep learning on histopathological images for colorectal cancer diagnosis: A systematic review. *Diagnostics*, 12(4), 837. <https://doi.org/10.3390/diagnostics12040837>
78. Fleming, M., Ravula, S., Tatishchev, S. F., & Wang, H. L. (2012). Colorectal carcinoma: Pathologic aspects. *Journal of Gastrointestinal Oncology*, 3(3), 153–173. <https://doi.org/10.3978/j.issn.2078-6891.2012.030>
79. Yokoyama, S., Watanabe, T., Fujita, Y., Matsumura, S., Ueda, K., Nagano, S., et al. (2023, April 13). Histology of metastatic colorectal cancer in a lymph node. *PLOS ONE*, 18(4), e0284536. <https://doi.org/10.1371/journal.pone.0284536>
80. Johncilla, M., & Yantiss, R. K. (2020, September). Histology of colorectal carcinoma. *Surgical Pathology Clinics*, 13(3), 503–520. <https://doi.org/10.1016/j.path.2020.04.002>
81. Selves, J., Long-Mira, E., Mathieu, M. C., Rochaix, P., & Ilić, M. (2018, April 5). Immunohistochemistry for diagnosis of metastatic carcinomas of unknown primary site. *Cancers*, 10(4), 108. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5923363/>
82. Bennedsen, A. L. B., Cai, L., Hasselager, R. P., Özcan, A. A., Mohamed, K. B., Eriksen, J. O., et al. (2022, January 14). An exploration of immunohistochemistry-based prognostic markers in patients undergoing curative resections for colon cancer. *BMC Cancer*, 22, 62. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8759288/>
83. Theiss, A. P., Chafin, D., Bauer, D. R., Grogan, T. M., & Baird, G. S. (2014, November 19). Immunohistochemistry of colorectal cancer biomarker phosphorylation requires controlled tissue fixation. *PLOS ONE*, 9(11), e113608. <https://doi.org/10.1371/journal.pone.0113608>
84. Rezaei, N. (2020). *Cancer immunology: A translational medicine context* (2nd ed.). Cham, Switzerland: Springer. <https://doi.org/10.1007/978-3-030-29286-7>
85. Chambers, P., Wei, L., Forster, M. D., Kipps, E., Wong, I. C. K., & Jani, Y. (2021, September 28). Evidence to guide the optimal timing for pre-chemotherapy blood tests for early breast, colorectal cancer and diffuse large B-cell lymphoma. *Cancer Medicine*, 10(22), 7996–8004. <https://doi.org/10.1002/cam4.4287>
86. Warr, J., Hird, A. E., DeAngelis, C., Giotis, A., & Ko, Y. J. (2013, September). Baseline blood work before initiation of chemotherapy: What is safe in the real world? *Journal of Oncology Practice*, 9(5), e182–e185. <https://doi.org/10.1200/JOP.2013.000959>
87. Korde, L. A., Somerfield, M. R., Carey, L. A., Crews, J. R., Denduluri, N., Hwang, E. S., et al. (2021). Neoadjuvant chemotherapy, endocrine therapy, and targeted therapy for breast cancer: ASCO guideline. *Journal of Clinical Oncology*, 39(13), 1485–1505. <https://doi.org/10.1200/JCO.20.03399>
88. Sikov, W., Boughey, J., & Al-Hilli, Z. (2022). General principles of neoadjuvant management of breast cancer. In UpToDate. Retrieved from <https://www.uptodate.com/contents/general-principles-of-neoadjuvant-management-of-breast-cancer>
89. Wang, H., & Mao, X. (2020, June). Evaluation of the efficacy of neoadjuvant chemotherapy for breast cancer. *Drug Design, Development and Therapy*, 14, 2423–2433. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7308147/>
90. Xie, Y. H., Chen, Y. X., & Fang, J. Y. (2020, March 20). Comprehensive review of targeted therapy for colorectal cancer. *Signal Transduction and Targeted Therapy*, 5(1), 22. <https://www.nature.com/articles/s41392-020-0116-z>
91. Dohrn, N., & Klein, M. F. (2023, April 20). Colorectal cancer: current management and future perspectives. *British Journal of Surgery*, 110(10), 1256–1259. <https://doi.org/10.1093/bjs/znad060>
92. National Cancer Institute. (2019). Advances in colorectal cancer research. <https://www.cancer.gov/types/colorectal/research>
93. National Cancer Institute. (2019). Genetics of colorectal cancer. <https://www.cancer.gov/types/colorectal/hp/colorectal-genetics-pdq>
94. Center for Drug Evaluation and Research. (2023, January 19). FDA grants accelerated approval to tucatinib with trastuzumab for colorectal cancer. U.S. Food and Drug Administration. <https://www.fda.gov/drugs/resources-information-approved-drugs/fda-grants-accelerated-approval-tucatinib-trastuzumab-colorectal-cancer>
95. An, X., Lei, X., Huang, R., Luo, R., Li, H., Xu, F., et al. (2020). Adjuvant chemotherapy for small, lymph node-negative, triple-negative breast cancer: A single-center study and a meta-analysis of the published literature. *Cancer*, 126(S16), 3837–3846. <https://doi.org/10.1002/cncr.32946>
96. Steenbruggen, T. G., van Werkhoven, E., van Ramshorst, M. S., Dezentjé, V. O., Kok, M., Linn, S. C., et al. (2020).

- Adjuvant chemotherapy in small node-negative triple-negative breast cancer. *European Journal of Cancer*, 135, 66–74. <https://doi.org/10.1016/j.ejca.2020.04.034>
97. Fehrenbacher, L., Cecchini, R. S., Geyer, C. E., Jr., Rastogi, P., Costantino, J. P., Atkins, J. N., et al. (2020). NSABP B-47/NRG Oncology phase III randomized trial comparing adjuvant chemotherapy with or without trastuzumab in high-risk invasive breast cancer negative for HER2 by FISH and with IHC 1+ or 2+. *Journal of Clinical Oncology*, 38(5), 444–453. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7007289/>
 98. Denduluri, N., Somerfield, M. R., Chavez-MacGregor, M., Comander, A. H., Dayao, Z., Eisen, A., et al. (2021). Selection of optimal adjuvant chemotherapy and targeted therapy for early breast cancer: ASCO guideline update. *Journal of Clinical Oncology*, 39(6), 685–693. <https://doi.org/10.1200/JCO.20.03026>
 99. Møller, T., Andersen, C., Lillelund, C., Bloomquist, K., Christensen, K. B., Ejlersen, B., et al. (2020). Physical deterioration and adaptive recovery in physically inactive breast cancer patients during adjuvant chemotherapy: A randomised controlled trial. *Scientific Reports*, 10(1), 9741. <https://doi.org/10.1038/s41598-020-66682-6>
 100. Shien, T., & Iwata, H. (2020). Adjuvant and neoadjuvant therapy for breast cancer. *Japanese Journal of Clinical Oncology*, 50(3), 225–229. <https://ousar.lib.okayama-u.ac.jp/files/public/5/59905/20200616102616861531/fulltext.pdf>
 101. American Cancer Society. (2020). Colorectal cancer chemotherapy | Chemo for colon & rectal cancer. <https://www.cancer.org/cancer/types/colon-rectal-cancer/treating/chemotherapy.html>
 102. Trinh, A., Trumpi, K., De Sousa E Melo, F., Wang, X., de Jong, J. H., Fessler, E., et al. (2017). Practical and robust identification of molecular subtypes in colorectal cancer by immunohistochemistry. *Clinical Cancer Research*, 23(2), 387–398. <https://aacrjournals.org/clincancerres/article/23/2/387/274981/Practical-and-Robust-Identification-of-Molecular>
 103. Dohrn, N., & Klein, M. F. (2023). Colorectal cancer: current management and future perspectives. *British Journal of Surgery*, 110(10), 1256–1259. <https://doi.org/10.1093/bjs/znad060>
 104. André, T., Meyerhardt, J., Iveson, T., Sobrero, A., Yoshino, T., Souglakos, I., et al. (2020). Effect of duration of adjuvant chemotherapy for patients with stage III colon cancer (IDEA collaboration): Final results from a prospective, pooled analysis of six randomised, phase 3 trials. *The Lancet Oncology*, 21(12), 1620–1629. <https://pubmed.ncbi.nlm.nih.gov/33271092/>
 105. Taieb, J., & Gallois, C. (2020). Adjuvant chemotherapy for stage III colon cancer. *Cancers*, 12(9), 2679. <https://doi.org/10.3390/cancers12092679>
 106. Farrar, M. C., & Jacobs, T. F. (2021). Paclitaxel. In *StatPearls*. Treasure Island (FL): StatPearls Publishing. <https://www.ncbi.nlm.nih.gov/books/NBK536917/>
 107. Aldossary, S. A. (2019). Review on pharmacology of cisplatin: Clinical use, toxicity and mechanism of resistance of cisplatin. *Biomedical and Pharmacology Journal*, 12(1), 7–15. <https://biomedpharmajournal.org/vol12no1/review-on-pharmacology-of-cisplatin-clinical-use-toxicity-and-mechanism-of-resistance-of-cisplatin/>
 108. Vodenkova, S., Buchler, T., Cervená, K., Veskrnová, V., Vodicka, P., & Vymetalková, V. (2020). 5-Fluorouracil and other fluoropyrimidines in colorectal cancer: Past, present and future. *Pharmacology & Therapeutics*, 206, 107447. <https://doi.org/10.1016/j.pharmthera.2019.107447>
 109. Cheng, F., Zhang, R., Sun, C., Ran, Q., Zhang, C., Shen, C., et al. (2023). Oxaliplatin-induced peripheral neurotoxicity in colorectal cancer patients: Mechanisms, pharmacokinetics and strategies. *Frontiers in Pharmacology*, 14. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10427877/>
 110. Devanabanda, B., & Kasi, A. (2021). Oxaliplatin. In *StatPearls*. Treasure Island (FL): StatPearls Publishing. <https://www.ncbi.nlm.nih.gov/books/NBK557690/>
 111. BC Cancer. (2023). Breast Cancer Drug Manual. <https://www.bccancer.bc.ca>
 112. Hegde, V. S., & Nagalli, S. (2023). Leucovorin. In *StatPearls*. Treasure Island (FL): StatPearls Publishing. <https://www.ncbi.nlm.nih.gov/books/NBK553114/>
 113. Hamed, K. M., Dighriri, I. M., Baomar, A. F., Alharthy, B. T., Alenazi, F. E., Alali, G. H., et al. (2022). Overview of methotrexate toxicity: A comprehensive literature review. *Cureus*, 14(9), e29448. <https://doi.org/10.7759/cureus.29448>
 114. American Cancer Society. (2021). Chemotherapy for breast cancer | Breast cancer treatment. <https://www.cancer.org/cancer/types/breast-cancer/treatment/chemotherapy-for-breast-cancer.html>
 115. Lee, S. (2018). Chemotherapy for colorectal cancer. *Canadian Cancer Society*. <https://cancer.ca/en/cancer-information/cancer-types/colorectal/treatment/chemotherapy>
 116. Kuter, D. J. (2022). Treatment of chemotherapy-induced thrombocytopenia in patients with non-hematologic malignancies. *Haematologica*, 107(6), 1243–1263. <https://haematologica.org/article/view/haematol.2021.279512>
 117. Song, B., Zhou, S., Li, C., Zheng, H., Zhang, X., Jin, X., et al. (2022). A prediction model for chemotherapy-induced thrombocytopenia based on real-world data and a close relationship between AST/ALT ratio and Plt count in patients with solid tumors. *International Journal of General Medicine*, 15, 8003–8015. <https://www.dovepress.com/a-prediction-model-for-chemotherapy-induced-thrombocytopenia-based-on-peer-reviewed-fulltext-article-IJGM>
 118. Madeddu, C., Gramignano, G., Astara, G., Demontis, R., Sanna, E., Atzeni, V., et al. (2018). Pathogenesis and treatment options of cancer related anemia: Perspective for a targeted mechanism-based approach. *Frontiers in Physiology*, 9, 1590. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6159745/>
 119. Anand, S., Burkenroad, A., & Glaspy, J. A. (2020). Workup of anemia in cancer. *Clinical Advances in Hematology & Oncology*, 18(10), 6406.
 120. Jang, J. H., Kim, Y., Park, S., Kim, K., Kim, S. J., Kim, W. S., et al. (2020). Efficacy of intravenous iron treatment for chemotherapy-induced anemia: A prospective Phase II pilot clinical trial in South Korea. *PLOS Medicine*, 17(6), e1003091. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7279571/>
 121. Pourali, L., Taghizadeh, A., Akhoundi, M. R., Varshoei, F., Zarifian, A., & Sheikh Andalibi, M. S. (2016, September 27). Frequency of chemotherapy induced anemia in breast cancer patients. *Iranian Journal of Cancer Prevention*.

-
122. Sritharan, S., & Sivalingam, N. (2021). A comprehensive review on time-tested anticancer drug doxorubicin. *Life Sciences*, 278, 119527. <https://pubmed.ncbi.nlm.nih.gov/33887349/>
123. Skverchinskaya, E., Levdarovich, N., Ivanov, A., Mindukshv, I., & Bukatin, A. (2023). Anticancer drugs paclitaxel, carboplatin, doxorubicin, and cyclophosphamide alter the biophysical characteristics of red blood cells, in vitro. *Biology*, 12(2), 230. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9953263/>