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Prevalence of Hepatocellular Carcinoma and Evaluation of Hematological Alterations among Patients in Northwest Libya

Almoatassem Bellah Mansour Alshoukry[1*], YumnaA. A. AL- Shaafi[2], Hanan A. E. AL-hbat[3], Heba K. M. Abo-gofa[4], and RawaceM.A.AL-Kanoni[5].

[1-5]Department of Medical Laboratories, AL- Garaboulli Higher Institute of Science and Medical Technology

***Corresponding Author Email: almoatassembellah@gmail.com**

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Abstract

Background: Hepatocellular carcinoma (HCC) is one of the most important challenges in global oncology with profound metabolic derangements, specific enzymatic modifications and systemic homeostatic changes. Clinical laboratory surveillance of hematological baseline parameters is an important non-invasive diagnostic tool to monitor cellular cytotoxicity, to assess the physiological course of malignancy and to identify secondary systemic stress before clinical manifestation. **Objectives:** The aim of this study was to determine the prevalence ofHepatocellular Carcinoma, andevaluatehematological changes associated with the clinical progression of hepatocellular carcinoma. The clinical effect of age and gender on the major laboratory profiles was specifically studied. **Methodology:** A cross-sectional laboratory-based study was conducted over a period of four months (February-May 2026). Clinical and laboratory data sets were assembled based on confirmed cases of HCC from large regional oncology centers. Statistical analysis was carried out using descriptive indices, independent t-test and effect size (Cohen's d) calculations with SPSS. **Results:** The epidemiological indicators showed a significant vulnerability in advanced age, the critical mass of cases (96.25%) being concentrated in cohorts over forty years, with a predominance of men (60%). Hematologic assessment showed a unique inflammatory and defensive response with a rapid increase in the counts of White Blood Cells (WBC) and Platelets (PLTs), with red blood cell indices (RBCs and MCH) temporarily within the normal range. **Conclusion:** The epidemiological indicators of this study established a robust correlation between advanced age and the clinical manifestation of hepatocellular carcinoma, with the critical mass of cases (96.25%) concentrated in patient cohorts exceeding forty years of age, Furthermore, a pronounced gender disparity was recorded in favor of males (60%).The secondary inflammatory hematological changes caused by progression of HCC. This underscores the clinical need for multi-parametric diagnostic surveillance, as isolated use of baseline laboratory profiles without radiological correlation can lead to misleading clinical interpretation delaying prognosis.

Keywords: Hepatocellular Carcinoma (HCC), Hematological Profile, Tumor Dynamics.

1.Introduction

HCC is a complex malignancy that causes systemic disturbances in both biochemical and hematological parameters. The clinical challenge lies in the symptomatic overlap between liver cirrhosis and cancer progression. This highlights the importance of studying the hematological alterations, such as abnormalities in platelet indices and complete blood counts (CBC). The tumor destroys functional hepatic tissue, leading to enzyme leakage and the liver's failure to maintain blood cell homeostasis. The integration of these measurements provides a comprehensive perspective on the patient's health status and the extent of disease progression.[1, 2]

Hematological changes in patients with Hepatocellular Carcinoma (HCC) arise as a result of the body's response to rapid tumor growth and oxidative stress. While hematological changessuch as anemia and thrombocytopeniareflect chronic inflammation and the impairment of coagulation functions synthesized by theliver, Therefore, studying these hematological changes collectively provides researchers with a deeper understanding of how the tumor dominates the body's vital biological processes.[3-5]

Hematological changes in patients with Hepatocellular Carcinoma (HCC) are characterized by their diversity and close correlation with the stage of tumor progression. While advanced cases lead to distinct disturbances such as thrombocytopenia and anemiaresulting from splenomegaly and the liver's biosynthetic failure**,**many patients may maintain hematological indices within or near normal limits during the initial or stable stages of the disease **,** This relative stability in the Complete Blood Count (CBC) makes the study of these cases a scientific necessity to understand clinical variation and to determine the sensitivity of routine tests in detecting early functional deterioration.[3, 6, -7]

The clinical significance of evaluating routine hematological changes lies in their ability to provide an initial and rapid overview of the liver's functional status and to monitor the patient's response to treatment **,** However, the fact that these markers remain within normal ranges in some patients does not rule out neoplastic activity; rather, it reflects the complex nature of Hepatocellular Carcinoma (HCC) and the liver's compensatory capacity during stable stages.[8, 9]

Therefore, reliance on these tests requires a systematic integration with more accurate and specialized diagnostic tools, most notably tumor markers such as Alpha-Fetoprotein (AFP), and advanced imaging techniques like Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) to precisely determine the size and stage of the tumor **,** The study of these routine variables remains the cornerstone of periodic patient assessment, as even a slight shift in these parameters may serve as an early indicator of clinical deterioration or tumor recurrence.[10]

Although the definitive diagnosis of hepatic tumors relies on gold-standard modalities such as magnetic resonance imaging (MRI) or histopathological biopsy, routine laboratory investigations remain an indispensable tool, The academic utility of these assays lies in their capacity for continuous functional assessment and clinical monitoring of the patient's status; as they provide vital biomarkers reflecting hepatic efficiency and the overall physiological state, thereby contributing to disease prognosis and the effective evaluation of therapeutic response**.**[11]

The research problem lies in the significant discrepancy between the clinical progression of liver cancer and the routine laboratory indicators used for its monitoring. Despite the aggressive nature of this disease, many patients may exhibit results that are near the normal range in common tests, such as Complete Blood Count (CBC).This proximity to normal levels may lead to difficulty in accurately assessing disease progression or the body's physiological response using these traditional tools alone. Therefore, there is an urgent need to investigate subtle hematological changes.

This apparent stability in laboratory results may lead to an underestimation of the actual functional deterioration, raising a fundamental question regarding the sensitivity of these routine tests as standalone tools for monitoring and evaluation. Accordingly, the research problem is defined as 'monitoring and analyzing the hematological changes in a sample of HCC patients, and demonstrating the extent to which these traditional indicators reflect the pathological reality and determine the actual need for integration with more precise diagnostic examinations.

2. Objectives

The aim of this study was to determine the prevalence ofHepatocellular Carcinoma, andevaluate hematological changes associated with the clinical progression of hepatocellular carcinoma. The clinical effect of age and gender on the major laboratory profiles was specifically studied.

3. Materials and Methods

3.1 Study Setting:

The present study was conducted across two major healthcare institutions in Libya:
The National Cancer Institute (NCI) - Misrata: A specialized center providing comprehensive oncological care for patients in the central region.
Tripoli University Hospital (TUH): One of the largest tertiary referral hospitals in the capital, providing advanced medical services and laboratory diagnostics.
Data were retrieved from the archived medical records of patients diagnosed with Hepatocellular Carcinoma (HCC).

3.2 . Sample Size and Limitations.

A significant challenge encountered during this study was the relative rarity of HCC cases compared to other oncological malignancies. Even within a specialized facility such as the National Oncology Institute, the number of eligible cases remained limited. During the established study period (2020–2025), a total of 88 files were initially identified at the NOI, with the following annual distribution:

- 2021: 13 cases
- 2022: 20 cases
- 2023: 19 cases
- 2024: 16 cases
- 2025: 20 cases.

Upon rigorous clinical review, only 46 files met the inclusion criteria, primarily due to the availability of complete diagnostic and follow-up data. To enhance the study's statistical depth, an additional 34 cases were successfully integrated from Tripoli University Hospital, bringing the total sample size to 80 cases.

- Data Collection: The data for this study were collected between February and May 2026.

3.3 Study Population and Sampling:

The study involved a total of 80 patients recruited from the National Cancer Institute in Misrata and Tripoli University Hospital. The sample represented various age groups, primarily focusing on the 3rd and 4th decades of life (40 years and older). The study population was mixed, including both male and female patients.

3.4 Data Collection:

Data were collected retrospectively from patients' medical records. This included clinical information and results for the specific biochemical and hematological parameters required for the study.

3.5 Laboratory Instrumentation and Analytical Procedures

To ensure high analytical precision, all hematological parameters were processed using standardized automated systems as follows:

Sample Preparation: Venous blood samples were collected into plain tubes for biochemical profiling and EDTA tubes for hematological evaluation.

Hematological Analysis: Complete Blood Count (CBC) parameters—including RBC count, Hemoglobin, MCH, WBC count with differential profiles, and Platelet (PLT) counts—were analyzed using a Sysmex Automated Hematology Analyzer, which utilizes advanced Flow Cytometry technology for precise cellular quantification.

Quality Control: Following quality control verification by specialized laboratory technicians, the automated outputs were integrated into the statistical database for final analysis.

Technical Training and Procedural Validation

Due to the critical health status of the target patients and strict administrative and legal protocols regarding direct sample manipulation, clinical data were retrieved retrospectively. To bridge the gap in practical experience and ensure procedural proficiency, the research team completed a training program at the Misrata Oncology Hospital, which focused on the following:

Clinical Observation: Actively observing laboratory technicians to gain a thorough understanding of the operational workflows, instrument usage, and analysis protocols within the hospital laboratory.

Technical Familiarization: Gaining comprehensive insight into the facility's testing methodologies and operational standards.

Skill Enhancement: Engaging in self-directed development of laboratory techniques to ensure a thorough grasp of the procedures and instrumentation required for the study.

3.6. Statistical Analysis

To achieve the research objectives and test the hypotheses, data were statistically analyzed using the Statistical Package for the Social Sciences (SPSS). The statistical procedures and tests applied in this study included the following:

Descriptive Statistics:

This was utilized as an initial analytical step to summarize and organize the raw laboratory data, providing a comprehensive overview of the sample's baseline characteristics. It involved computing the following parameters:

1. Arithmetic Mean: To determine the central value and average level of each biochemical and hematological parameter among the patients.

2. Standard Deviation: To measure the degree of dispersion and variation of the laboratory readings around their respective means.

3. Minimum and Maximum Values: To define the clinical range of observed values and identify any extreme deviations or acute clinical shifts.

One-Sample T-Test:

This inferential test was employed to compare the arithmetic means of the sample's biochemical and hematological variables against clinically established standard reference ranges (normal values). The

objective was to determine whether the deviations observed in liver cancer patients were statistically significant (Sig. < 0.05) and attributable to pathological alterations rather than mere chance.

Effect Size (Cohen's d):

Following the confirmation of statistical significance via the T-test, Cohen's d was computed to determine the practical and applied significance of the observed differences. This measure evaluates the actual magnitude of the disease's impact on the examined biological markers.

Cronbach's Alpha Coefficient:

This metric was utilized to evaluate the internal consistency and reliability of the laboratory dataset. It ensured the stability, consistency, and structural integrity of the measurements prior to drawing final scientific conclusions.

4. Results

4.1. Distribution of the Study Sample According to Gender

Table (1) presents the demographic characteristics of the study sample in terms of gender. The statistical data reveal a noticeable variation in the numerical and proportional distribution between males and females. Males represented the largest proportion of the sample, with 48 cases, accounting for 60.0% of the total sample.

In contrast, females accounted for 32 cases, representing 40.0% of the sample. These findings indicate a clear predominance of males within the study population, which is consistent with several epidemiological studies suggesting higher rates of liver tumors among males compared to females, due to the interaction of various biological, environmental, and lifestyle-related factors.

This demographic structure reflects a realistic representation of cases attending treatment centers in the study area, thereby enhancing the researcher's ability to analyze gender as a moderating variable in the development of subsequent biochemical and biological indicators.

Table (1): Distribution of the Study Sample According to Gender

Gender	Frequency	Percent
Male	**48**	**60.0%**
Female	**32**	**40.0%**
Total	**80**	**100.0%**

4.2.Distribution of the study sample according to age groups.

Table (2) and figure (1)illustrates the age structure of the study sample members, where the data reveal a clear concentration of cases among older age groups. The category "Over 61 years" ranked first with a frequency of (46) cases, representing (57.5%) of the total, followed immediately by the "41 to 60 years" category with a frequency of (31) cases and a percentage of (38.75%).

When examining the cumulative percentages, approximately (96.25%) of the total sample falls within the age group exceeding 40 years. In contrast, younger age groups showed a sharp decline; the "21 to 40 years" category accounted for approximately (2.5%), while the "0 to 20 years" category recorded the lowest frequency at only (1.25%).

These findings statistically and medically confirm the existence of a strong positive correlation between advancing age and the increased likelihood of developing hepatic tumors, which is consistent with the medical literature attributing this to the cumulative temporal exposure to pathological agents and the progressive weakening of cellular compensatory mechanisms with age.

Table (2): Distribution of Sample Members by Age Groups

Age Group(years)	Frequency	Percent
≤20	**1**	**1.25%**
21 - 40	**2**	**2.5%**
41 - 60	**31**	**38.75%**
Over 61 years	**46**	**57.5%**
Total	**80**	**100.0%**

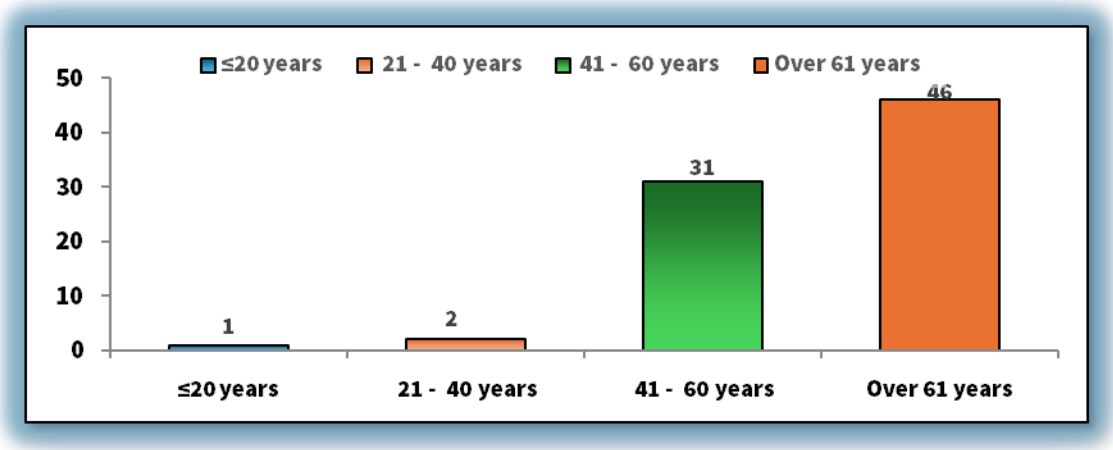

Figure (1): Distribution of the study sample according to age groups.

4.3. Distribution of Sample Members by Year of Diagnosis

Table No. (3)and figure (2) presents the temporal distribution of diagnosed cases among the study sample members, where the results reveal a notable time spread in the periods of disease detection, with a significant concentration in recent years. The year 2023 recorded the highest frequency of cases with (24) cases representing (30.0%), followed immediately by 2025 with (23) cases and a percentage of (28.75%), then 2024 with (17) cases and a percentage of (21.25%).

When analyzing the temporal trend based on the cumulative percentage, it is observed that approximately (80.0%) of the sample cases were diagnosed during the last three years (2023–2025), while the earlier years (2020–2022) recorded very low frequencies; the proportion of cases diagnosed in 2020 amounted to only approximately (1.25%).

These findings are statistically interpreted as indicating an increase in case detection or a rise in attendance rates at treatment centers in the study area in recent times. The data also reflect the recent onset of disease in the majority of the sample, which constitutes a critical variable when examining biochemical indicators, as newly detected cases may represent different stages of the clinical progression of the disease compared to older cases.

Table (3): Distribution of Sample Members by Year of Diagnosis

Year of Diagnosis	Frequency	Percent
2020	1	1.25%
2021	12	15.0%
2022	3	3.75%
2023	24	30.0%
2024	17	21.25%
2025	23	28.75%
Total	80	100.0%

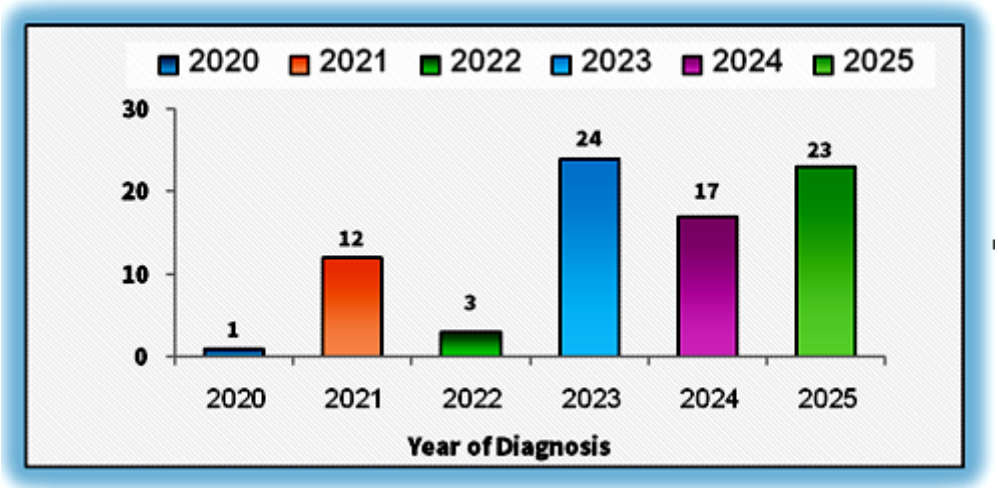

Figure (2): Distribution of Sample Members by Year of Diagnosis

4.4. Distribution of Sample Members by Red Blood Cell (RBC) Categories

(Normal reference range: 4.2 – 5.9)

Table (4) and figure (3) presents the hematological status of the study sample members in terms of red blood cell count, which is a vital biomarker reflecting the efficiency of tissue oxygenation and the general nutritional status of the patients. The results reveal a clear statistical shift toward lower categories; the "Low" category (less than 4.2) recorded the highest frequency with (53) cases, representing (66.25%).

This finding statistically indicates that two-thirds of the study sample suffer from anemia, a prevalent phenomenon in hepatic tumors resulting from several factors, including the effect of chronic disease on bone marrow function, deficient secretion of the hormone erythropoietin, or malnutrition and loss of appetite commonly associated with cancer.

In contrast, (26) cases-maintained levels within the "Normal" range (4.2 – 5.9) at a rate of (32.5%), reflecting the capacity of vital systems in this subset to sustain balanced blood cell production despite the presence of tumorous pathology. Meanwhile, only (1) case (1.25%) was recorded in the "High" category, representing an exceptional instance that may be associated with rare compensatory mechanisms or other pathological interactions.

The correspondence of the Valid Percent (100%) with the overall percentage confirms the completeness of laboratory records for all (80) sample members, thereby enhancing the reliability of the analysis and affirming that disturbances in red blood cell count constitute a prominent feature among the majority of affected individuals in the study area.

Table (4): Distribution of Sample Members by Red Blood Cell (RBC) Categories*(Normal reference range: 4.2 – 5.9)*

RBC Category	Frequency	Percent
Low (less than 4.2)	**53**	**66.25%**
Normal (4.2 – 5.9)	**26**	**32.5%**
High (greater than 5.9)	**1**	**1.25%**
Total	**80**	**100.0%**

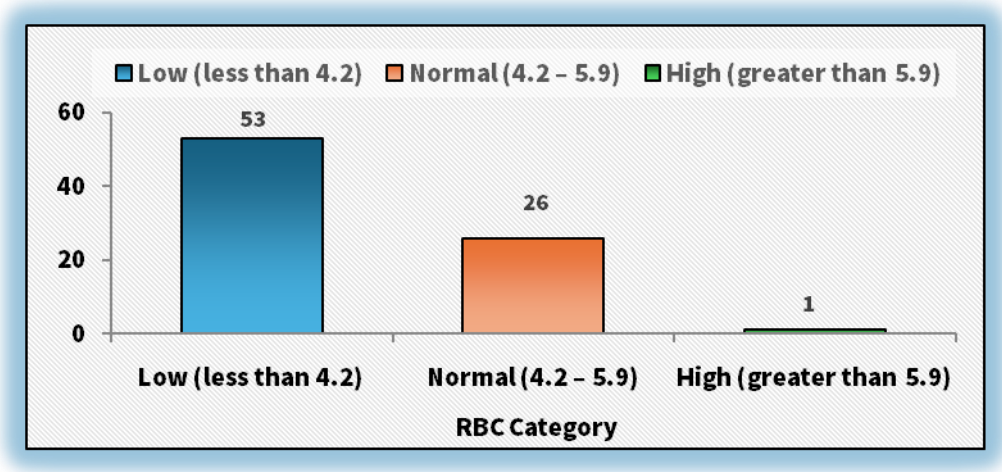

Figure (3): Distribution of the study sample according to red blood cell (RBC) count categories.

4.5. Distribution of Sample Members by White Blood Cell (WBC) Categories

(Normal reference range: 4.5 – 11.0)

Table **(5)**and figure (4) presents the immunological and inflammatory status of the study sample members through the measurement of white blood cell count, a biomarker reflecting the body's physiological response to the presence of tumorous cells or secondary disease-related infections. The results show that the prevailing pattern within the sample is stability within reference limits; the "Normal" category (4.5 – 11.0) recorded the highest frequency with (48) cases, representing (60.0%).

This proportion statistically indicates that the vast majority of patients exhibited neither acute immune reactions nor a severe decline in immunity at the time of examination, reinforcing the hypothesis of "functional compensation" and the temporary stability of the immune system in the face of tumorous

progression. In contrast, the results revealed (19) cases representing (23.75%) falling within the "Low" category (less than 4.5), which may be clinically interpreted as reflecting the disease's impact on splenic function, such as splenomegaly, or bone marrow insufficiency in certain cases.
The "High" category (greater than 11.0) recorded (13) cases at a rate of (16.25%). This elevation reflects the presence of an active inflammatory response or secondary infection in this subset, which is a common occurrence in advanced stages of hepatic tumors that may be accompanied by tissue necrosis followed by an immune reaction.

Table (5): Distribution of Sample Members by White Blood Cell (WBC) Categories*(Normal reference range: 4.5 – 11.0)*

WBC Category	Frequency	Percent
Low (less than 4.5)	**19**	**23.75%**
Normal (4.5 – 11.0)	**48**	**60.0%**
High (greater than 11.0)	**13**	**16.25%**
Total	**80**	**100.0%**

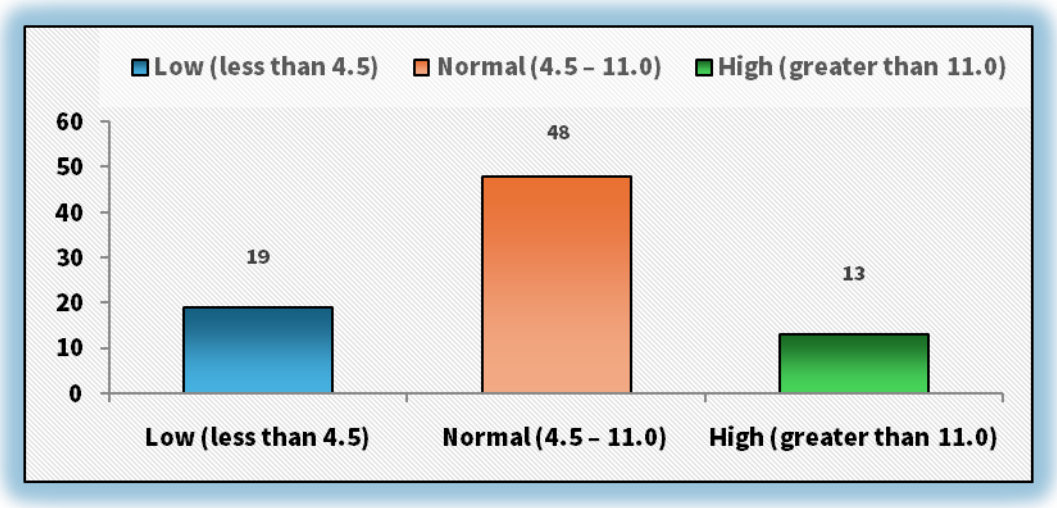

Figure (4): Distribution of the study sample according to white blood cell (WBC) count categories.

4.6. Distribution of Sample Members by Platelet Categories*(Normal reference range: 150 – 450)*

Table **(6)**and figure (5) presents the coagulation status of the study sample members through the measurement of platelet count, a vital biomarker reflecting the efficiency of hemostasis and the impact of hepatic alterations on bone marrow and splenic function. The results show that the prevailing pattern tends toward stability within reference limits; the "Normal" category (150 – 450) recorded the highest frequency with (50) cases, representing (62.5%).
This proportion statistically indicates that the vast majority of patients still possess sufficient compensatory capacity to maintain platelet levels within the safe range, thereby reducing the risk of spontaneous bleeding at this stage of the study. In contrast, the results revealed (26) cases representing (32.5%) falling within the "Low" category (less than 150). This phenomenon is clinically explained by its close association with deteriorating hepatic function, which may lead to congestive splenomegaly and accelerated platelet destruction, or result from deficient secretion of thrombopoietin, a hormone primarily synthesized in the liver.
The "High" category (greater than 450) recorded the lowest frequency with only (4) cases at a rate of (5.0%), representing instances that may be associated with acute inflammatory reactions or secondary responses to tumorous activity.

Table (6): Distribution of Sample Members by Platelet Categories*(Normal reference range: 150 – 450)*

Platelet Category	Frequency	Percent	Valid Percent
Low (less than 150)	26	32.5%	32.5%
Normal (150 – 450)	50	62.5%	62.5%
High (greater than 450)	4	5.0%	5.0%
Total	80	100.0%	100.0%

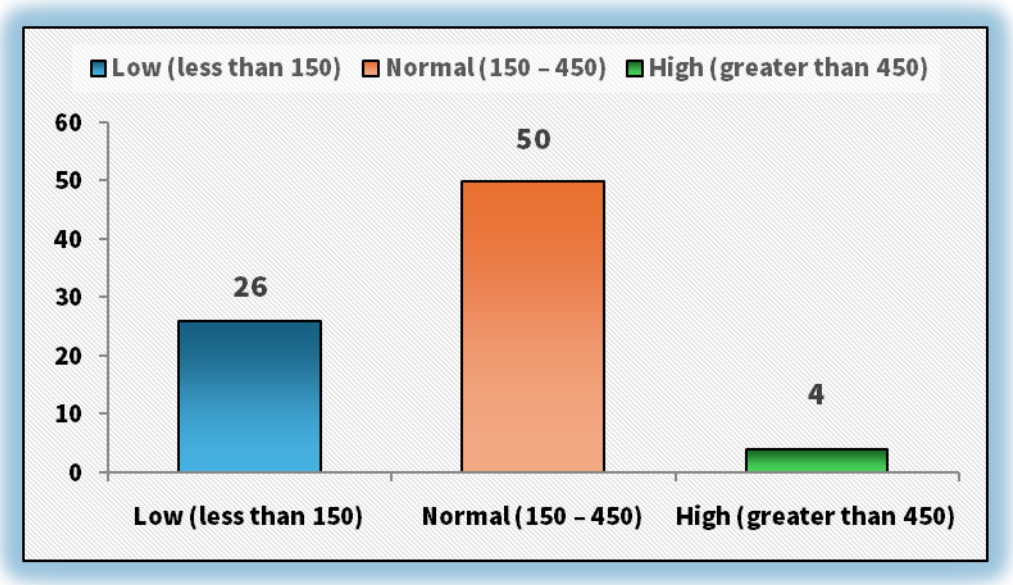

Figure (5): Distribution of the study sample according to platelet count categories.

4.7. Descriptive Statistics for the Blood Analysis Section

Table **(7)** presents the descriptive statistical indicators for the primary blood components among the study sample members. These figures reveal sharp variations reflecting the complex interplay between the pathological condition and the body's compensatory mechanisms in confronting hepatic tumors.

Regarding Mean Corpuscular Hemoglobin (MCH), the arithmetic mean settled at (31.81), a value that statistically falls within the upper-normal range. Nevertheless, the data reveal exceptional dispersion; the minimum value reached (7.50) while the maximum reached (287.00), resulting in a very high standard deviation of (30.56). This considerable variation indicates the presence of cases suffering from severely acute anemia alongside cases recording atypically elevated figures, potentially reflecting disorders in the quality of blood cell production in a limited subset of patients.

As for Red Blood Cells (RBC), a mean of (4.09) million/mL was recorded, approaching the lower normal limit, with a relatively low standard deviation of (1.18). The proximity of the mean to the observed values indicates relative homogeneity in the sample's tendency toward reduced red blood cell count, with the minimum value reaching (1.83), confirming the prevalence of anemia among patients as a secondary consequence of chronic disease.

Regarding White Blood Cells (WBC), the arithmetic mean reached (8.16), falling precisely within the normal range. However, the wide range between the minimum value (1.90) and the maximum value (31.00), with a standard deviation of (5.56), illustrates variation in immune response; while the majority maintain a normal count through functional compensation, a minority of patients suffer from acute immune deficiency, while another minority exhibit a severely acute inflammatory response.

With respect to Platelets, the sample recorded a mean of (231.87), a value falling within safe limits. However, the high standard deviation (134.19) reflects considerable dispersion in the results; in some cases values dropped as low as (24.10), posing an acute hemorrhagic risk, while in other cases they rose to (584.00). This variation demonstrates that liver cancer does not affect coagulation balance in a uniform pattern across all patients, but rather depends on the condition of the spleen and the extent of bone marrow functional deterioration.

Table (7): Descriptive Statistics for the Blood Analysis Section

Statistical Variable	N	Minimum	Maximum	Mean	Std. Deviation
Mean Corpuscular Hemoglobin (MCH)	80	7.50	36.10	25.84	7.12
Red Blood Cells (RBC)	80	1.83	12.60	4.09	1.18
White Blood Cells (WBC)	80	1.90	31.00	8.16	5.56
Platelets	80	24.10	584.00	231.87	134.19

4.8. Results of the T-Test for Hematological Indicators

The results demonstrated a clear and statistically significant bias in the defensive and inflammatory components of the blood; both White Blood Cell (WBC) count and Platelets recorded a substantial elevation exceeding the lower normal limits at a statistically significant level of (0.000). The elevated t-value for white blood cells (5.891) with a mean difference of (3.66), and the t-value for platelets (5.457) with a mean difference of (81.87), indicate that the sample members are undergoing an active state of inflammatory response and secondary myeloid stimulation associated with the tumorous process. This increase narratively reflects the mobilization of the immune system and coagulation mechanisms as a reflexive response to the presence of cancerous cells and the accompanying tissue necrosis in the liver.

In contrast, the narrative analysis revealed a degree of stability or "functional resilience" in the oxygen transport system; the T-test results showed no statistically significant differences for hemoglobin (MCH) and Red Blood Cell (RBC) variables. Their significance levels reached (0.163) and (0.406) respectively, both exceeding the adopted significance threshold of (0.05). Although a slight decrease in the mean red blood cell count below the reference value was observed at (-0.11), this change remained within the statistically non-significant range. This indicates that the impact of liver cancer on red blood cell count and hemoglobin concentration in this sample has not yet reached a stage of comprehensive collapse, allowing the body to maintain levels close to the lower normal limits to ensure a minimum degree of tissue perfusion (Table. 8).

The study concludes that the most sensitive and statistically significant hematological changes among liver cancer patients in the study area are concentrated in white blood cell count and platelet count, both of which exhibit a clear proportional response to pathological activity. Meanwhile, red blood cell and hemoglobin indicators remain less affected at the current stages, directing statistical and clinical attention toward adopting inflammatory indicators as more effective tools for tracking the clinical progression of the disease among the study sample members.

Table (8): Results of the T-Test for Hematological Indicators

Variable	Test Value	t-value	Sig. (2-tailed)	Mean Difference	Direction of Change
Mean Corpuscular Hemoglobin (MCH)	27.00	1.408	0.163	4.81	Statistically non-significant
Red Blood Cells (RBC)	4.20	-0.835	0.406	-0.11	Non-significant decrease
White Blood Cells (WBC)	4.50	5.891	0.000	3.66	Statistically significant increase
Platelets	150.00	5.457	0.000	81.87	Statistically significant increase

4.9. Interpretation of Normal Laboratory Results Among Tumor Patients

The findings presented in Table **(9)** reveal that the human body possesses functional defense mechanisms that maintain vital indicators in a stable state despite the presence of the tumorous process, according to the following narrative analysis:

On the level of the hematological system, it was observed that the vast majority of patients (62.5%) maintained normal platelet levels. The scientific interpretation here indicates that bone marrow continues its compensatory production of platelets to offset any deficit resulting from mild splenomegaly or disease-related consumption, thereby maintaining platelet count within statistically safe limits for an extended period throughout the disease course.

Table (9): Interpretation of Normal Laboratory Results Among Tumor Patients

Laboratory Phenomenon	Percentage "Normal" in Sample	Scientific Interpretation (Functional Compensation)
Normal platelet count	62.5%	Continued compensatory production from bone marrow despite the presence of mild splenomegaly.

4. 10. Results of Pearson Correlation Test Between ALP Enzyme and Hemoglobin Indicator

1.There is no correlation between the severity of elevation in liver enzymes (ALP) and the deterioration of blood indicators such as hemoglobin (Hgb).

The null hypothesis stated that: "There is no correlation between the severity of elevation in liver enzymes (ALP) and the deterioration of blood indicators such as hemoglobin." To verify the validity of this hypothesis, the Pearson Correlation Coefficient was employed, and the results presented in Table **(10)** revealed the following:

The statistical analysis uncovered the existence of a moderate inverse correlation of statistical significance between the level of Alkaline Phosphatase (ALP) enzyme and the Mean Corpuscular Hemoglobin (MCH) indicator, with the correlation coefficient reaching (-0.342) at a significance level of (0.002), a value considerably below the adopted significance threshold of (0.05) (Figure.6).

This finding narratively indicates an inverse proportionality between the two variables; as ALP enzyme levels escalate due to tumorous activity or biliary obstruction in the liver, a gradual and progressive decline in hemoglobin concentration correspondingly follows among the sample members. This association is scientifically attributed to the systemic impact of liver cancer, whereby the acute elevation in biochemical indicators reflects an advanced stage of the disease, which is frequently accompanied by secondary suppression of hematopoietic processes or impaired absorption of the nutritional elements essential for hemoglobin synthesis.

Based on the preceding findings, the null hypothesis claiming the absence of a relationship is rejected, and the alternative hypothesis is accepted, confirming the existence of a statistically significant inverse correlation between the severity of liver enzyme elevation and the deterioration of the hemoglobin indicator among liver cancer patients in the study area. This demonstrates that hepatic enzymatic deterioration can be considered an inferential indicator of the general decline in the patient's hematological status.

2.There are no statistically significant differences in the complete blood count (CBC) indicators among liver cancer patients compared to normal reference rates.

Table (10): Results of Pearson Correlation Test Between ALP Enzyme and Hemoglobin Indicator

Correlated Variables	Correlation Coefficient (R)	Sig. (2-tailed)	Statistical Result
ALP Enzyme with Hemoglobin (MCH)	-0.342	0.002	Statistically significant (inverse relationship)

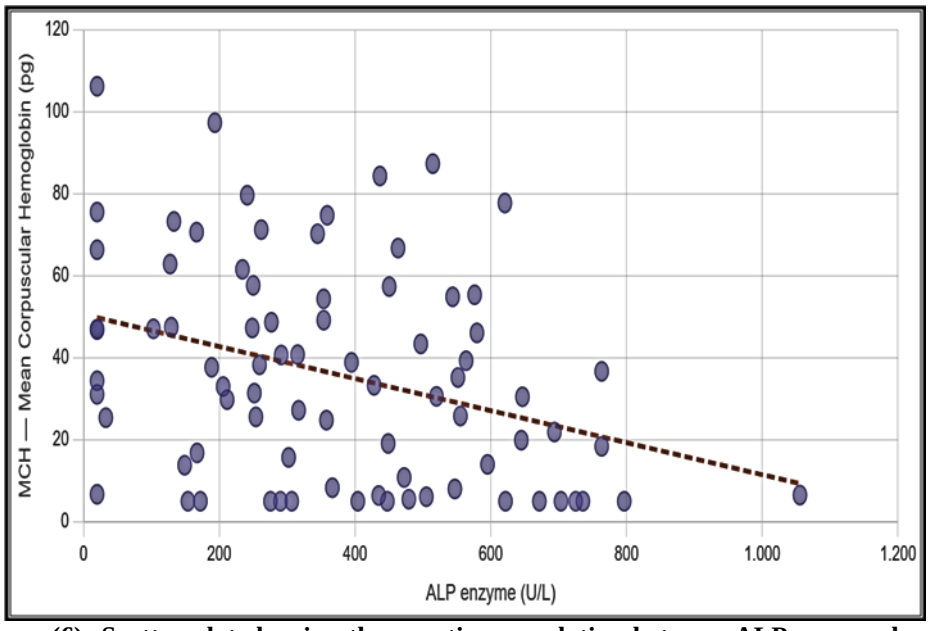

Figure (6): Scatter plot showing the negative correlation between ALP enzyme levels and Mean Corpuscular Hemoglobin (MCH).

4.11. Results of the T-Test for Complete Blood Count (CBC) Indicators

The null hypothesis stated that: "There are no statistically significant differences in the complete blood count (CBC) indicators among liver cancer patients compared to normal reference rates." To verify the validity of

this hypothesis, a One-Sample T-Test was conducted, and the results presented in Table **(11)** revealed a division in the hematological response among the examined variables:

The statistical analysis revealed a partial rejection of the null hypothesis with respect to White Blood Cells (WBC) and Platelets; these indicators recorded substantial statistically significant elevations at a significance level of (0.000). The arithmetic means of white blood cells (8.16) and platelets (231.87) significantly exceeded the reference values, reflecting the presence of an inflammatory response and a state of defensive mobilization within the hematological system to confront tumorous activity.

In contrast, the results revealed a partial acceptance of the null hypothesis with respect to Red Blood Cells (RBC) and the Hemoglobin (MCH) indicator; their significance levels reached (0.406) and (0.163) respectively, both exceeding the significance threshold of (0.05). This statistically indicates the absence of substantial differences between the sample means and the normal reference values for these indicators, implying that the respiratory system of the blood (oxygen transport) continues to maintain its equilibrium and has not been acutely affected by the disease in the majority of the sample members.

Based on the observed variation, the null hypothesis is generally rejected; as liver cancer has indeed produced statistically significant and substantial changes in the most critical components of the blood count (white blood cells and platelets). It is narratively concluded that the nature of the disease's hematological impact in the study area is "inflammatory-stimulatory" rather than "comprehensively destructive" to blood components, whereby red blood cells and hemoglobin demonstrated resilience while white blood cells and platelets responded to the clinical activity of the tumor.

Table (11): Results of the T-Test for Complete Blood Count (CBC) Indicators

Blood Indicator (CBC)	Mean	Test Value	t-value	Sig. (2-tailed)	Statistical Result
Red Blood Cells (RBC)	4.09	4.20	-0.835	0.406	Non-significant
White Blood Cells (WBC)	8.16	4.50	5.891	0.000	Statistically significant
Platelets	231.87	150.00	5.457	0.000	Statistically significant
Hemoglobin (MCH)	31.81	27.00	1.408	0.163	Non-significant

Following the verification of statistical significance, an Effect Size test (Cohen's d) was conducted to determine the practical and applied strength of the observed differences. The results reveal interpretive dimensions that extend beyond the mere "existence of a difference":

The results indicate that ALP enzyme recorded the highest effect size (0.73), meaning that the tumorous pathology exerts an immense and fundamentally significant pressure on the levels of this particular enzyme, rendering it the most clinically sensitive variable and the most profoundly affected by the disease. Similarly, the hematological indicators (white blood cells and platelets) demonstrated large effect sizes of (0.66) and (0.61) respectively, confirming that the inflammatory and defensive changes in the blood are not merely numerical differences, but rather deep-seated alterations reflecting the body's acute response to the tumor.

The effect size findings confirm that the greatest "explanatory power" in this study is concentrated in ALP enzyme and white blood cell count; these two variables demonstrated the greatest deviation from the normal range, rendering them the most "weighted" biomarkers in evaluating the clinical status of liver cancer patients in the study area(Table 12).

Table (12): Effect Size Measurement (Cohen's d) for Statistically Significant Variables

Variable	t-value	Effect Size (Cohen's d)	Interpretation (per Cohen` s d)
White Blood Cells (WBC)	5.891	0.66	Large effect
Platelets	5.457	0.61	Large effect

5. Discussion

Demographic Distribution and Its Association with Disease Prevalence - Gender & Age

The demographic analysis of the current study revealed a clear male predominance, accounting for 60% of HCC cases, with a sharp age concentration in individuals older than 40 years at 96.25%, and particularly in those above 61 years at 57.5%. This distribution reflects both physiological and behavioral determinants underlying hepatocarcinogenesis.

The male predominance can be physiologically explained by higher exposure to major risk factors among men, including chronic hepatitis B and C infections, tobacco smoking, and visceral fat accumulation, which collectively increase oxidative stress and hepatic inflammation. Furthermore, androgen-mediated pathways have been implicated in promoting hepatocyte proliferation and tumorigenesis, contributing to the gender disparity observed in HCC. The marked age-related increase is attributed to the progressive decline in

cellular DNA repair mechanisms and the cumulative exposure to carcinogenic agents over time, which aligns with the multistep model of hepatocarcinogenesis. Thus, age and gender represent non-modifiable but critical epidemiological determinants of HCC incidence.

This finding is supported by previous literature [12], which reported that HCC incidence is 2–4 times higher in males than females worldwide, primarily due to differential exposure to viral hepatitis and lifestyle risk factors. Similarly, another study [13], demonstrated that HCC risk increases exponentially after the age of 40 and peaks after 60 years, correlating with cumulative viral load, cirrhosis duration, and age-related genomic instability.

Inflammatory Response versus RBC Stability.

The current study showed a statistically significant increase in WBC and platelet counts ($p < 0.001$), while mean RBC and MCH values remained stable, despite the presence of anemia in the categorical distribution. This pattern indicates two parallel processes: a systemic inflammatory response and a compensatory mechanism to maintain oxygen transport.

The increase in WBC and platelets is consistent with a previous study [14], which reported that HCC stimulates cytokine production, leading to leukocyte activation and reactive thrombocytosis as part of the tumor-associated inflammatory response; This elevation is attributed to hepatic tissue injury and chronic inflammation, which are common in HCC,this agreement supports our interpretation that the rise in WBC and platelets reflects the body's inflammatory reaction to tumor presence.

At the same time, the stability of mean RBC and MCH is in line with another report [15], which noted that mean erythrocyte indices often remain within normal limits in early HCC stages due to compensatory erythropoiesis. This occurs as the body temporarily maintains red cell production to preserve oxygen delivery, even when anemia begins to appear in subgroups of patients. This concordance supports our finding that RBC parameters remain stable in the mean, while anemia is evident in the distribution analysis.

Clinical Utility and Surveillance Imperatives Despite Diagnostic Limitations

The results of this study show that routine laboratory tests have limited sensitivity for early HCC detection. Although liver enzymes, renal function, and mean RBC values were normal in many patients with confirmed malignancy; inflammatory markers like WBC and platelets showed significant elevation, this indicates that normal biochemical results do not exclude early HCC.

These findings are consistent with a previous study [16], which reported that standard liver function tests and AFP have low sensitivity in early stages, leading to the recommendation of imaging as the main diagnostic method; Our results also align with another report [17], which showed that ultrasound surveillance combined with AFP improves early detection, emphasizing that normal laboratory profiles alone cannot rule out malignancy.

6. Conclusions

The epidemiological indicators of this study established a robust correlation between advanced age and the clinical manifestation of hepatocellular carcinoma (HCC), with the critical mass of cases (96.25%) concentrated in patient cohorts exceeding forty years of age, Furthermore, a pronounced gender disparity was recorded in favor of males (60%), which strictly aligns with global and regional literature regarding the chronological accumulation of risk factors and gender-specific biological susceptibilities.

Thepatients'hematological profile exhibited a distinctive inflammatory and defensive pattern, characterized by a sharp, statistically significant elevation in White Blood Cells (WBCs) and Platelets (PLTs), driven by secondary bone marrow stimulation in response to tumoral tissue necrosis. Conversely, the oxygen-transport system (RBCs and MCH) maintained relative stability in its arithmetic means, displaying a temporary functional resilience to sustain systemic perfusion.

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