

A Study of Hematological and Hepatic Changes in Polycythemia Vera

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ARTICLE INFO

Article History:

Received: 17/5/2025

Accepted: 6/7/2025

Published: Summer 2026

Keywords:

Erythropoietin, JAK2

V617F Mutation,

Hematological

Parameters, Liver

Function Tests,

Polycythemia Vera (PV)

Doi:

10.25212/lfu.qzj.11.3.54

ABSTRACT

Polycythemia vera (PV) is a type of myeloproliferative neoplasm marked by the overproduction of red blood cells and strongly associated with mutations in the JAK2 gene. In this study, we examined and compared clinical, hematological, and biochemical features of individuals with PV and healthy control subjects to better understand the disease's distinguishing characteristics. A total of 227 patients with confirmed PV and 32 healthy individuals participated in the study. Data collected included demographic information, JAK2 V617F mutation status, and essential blood parameters such as red blood cell (RBC) count, hemoglobin (Hb) concentration, white blood cell (WBC) count, and platelet (PLT) count. In addition, liver function tests—including alkaline phosphatase (ALP) and aspartate aminotransferase (AST)—as well as erythropoietin (EPO) levels were evaluated to explore broader physiological effects. The JAK2 V617F mutation was found in 94% of PV patients ($p < 0.0001$), confirming its central role in disease pathogenesis. Compared to the healthy controls, PV patients showed significantly higher levels of hemoglobin, WBCs, and RBCs ($p < 0.001$), along with notably reduced levels of erythropoietin ($p = 0.0002$). We also found that ALP

levels declined with age ($p = 0.022$). Clinically, splenomegaly was present in 69.6% of patients, and bone marrow panmyelosis was observed in 96%. No meaningful associations were identified between liver enzyme levels and gender.

In conclusion, PV is characterized by increased blood cell production, a high prevalence of JAK2 mutations, and suppressed erythropoietin levels. The age-related changes in ALP and limited liver involvement provide further insight into the disease's progression. These findings emphasize the importance of molecular testing and regular blood monitoring to support accurate diagnosis and guide effective clinical management.

1. Introduction

Living with a condition like Polycythemia Vera (PV) means facing persistent and often distressing symptoms, such as intense itching following a warm shower, throbbing pain in the extremities, and the ongoing concern of serious complications like stroke or heart attack, even during periods of rest. For thousands of individuals affected by PV, these experiences represent a challenging and constant reality that significantly impacts their daily lives (1). Polycythemia vera (PV) is a rare, chronic blood cancer that disrupts the normal function of the bone marrow, leading to an overproduction of red blood cells. This imbalance creates a complex array of symptoms that challenge straightforward diagnosis and management, profoundly affecting patients' lives (2). First described in the early 20th century, PV has long puzzled clinicians and researchers alike. Unlike cancers that announce themselves with aggressive tumors, PV operates insidiously (3). Its hallmark a crimson tide of red cells masks a storm of molecular chaos: rogue mutations like JAK2 V617F that corrupt cellular communication, epigenetic shifts that rewrite genetic fate, and a body caught in the crossfire of inflammation and clot formation (4). Yet, behind every

elevated hematocrit level or thrombotic event lies a human story a patient navigating uncertainty, a family adjusting to lifelong vigilance, and a medical team balancing hope with the limits of current therapies (5).

In recent decades, breakthroughs in genetics have peeled back layers of PV's complexity, revealing how a single mutation can orchestrate systemic havoc (6). But science alone cannot capture the full narrative (7). The physiological toll—chronic fatigue, debilitating headaches, or the emotional weight of a cancer diagnosis is as profound as the molecular mechanisms driving the disease (8). This duality defines PV: it is both a cellular rebellion and a deeply human struggle (9). Starting from 2005, clonal abnormalities have been observed in the classic MPNs, indicating the presence of the acquired clone (6). The presence of the Janus kinase 2 (JAK2) V617F mutation was identified in 95% of patients diagnosed with PV and around 50% of individuals with ET and PMF (10). The primary clinical presentation of MPN, known as splenomegaly, is widely recognized for causing distressing symptoms such as early satiety, weakness, abdominal pain, and potential progression to severe complications such as cytopenia's resulting from splenic sequestration (11). Spleen enlargement, present in 10%-20% of ET patients at diagnosis. Splenomegaly is widely regarded as a distinguishing characteristic of PV; however, its reported occurrence in the literature varies between 20% and 75% (12). The general aim of this study is to investigate potential biomarkers-based locus genes with clinical prognosis in PV. To detect the frequency of JAK2 in the patients, estimation of some hematological parameters, and assesses the amount of Erythropoietin (EPO) hormone within PV patients.

2. Materials and Methods

2.1 Design of study

The current case-control study was carried out from October 2024 to April 2025. case group: 227 patients with different ages and gender participated in this research study at Nanakaly hospital for blood disorder and cancer in Erbil. Control group: randomly thirty-two people participated as healthy control

subject, none of them had evidence of any blood diseases and all were healthy volunteer individuals. The data includes demographic data, patient characteristics, and routine laboratory results including hematological parameters such as red blood cells count (RBCs), hemoglobin level (Hb), white blood cells count (WBCs), platelets count (Plts) and biochemical parameters such as serum ALT, AST, ALP and Serology test for erythropoietin (EPO). Inclusion criteria for polycythemia vera patients include those patients that confirmed diagnosis via 2016 WHO criteria (elevated hemoglobin/hematocrit, jack2 mutation and bone marrow findings), age ≥ 18 years and clinical status symptomatic/asymptomatic). Exclusions involve secondary polycythemia, other hematological disorders, other cancer patients, patients with liver and chronic disease. The informed consent was obtained from all the participants prior participation. The research project has been approved by the ethical committee of Koya University-Erbil, meeting the Helsinki Declaration criteria. The summary of the study is presented in table 1.

Table 1: Summary of Experimental Design and Procedures

Section	Details
Study Design	Case-control study conducted from October 2024 to April 2025.
Participants	- Case group: 227 diagnosed PV patients (confirmed by 2016 WHO criteria)- Control group: 32 healthy individuals without blood disorders.
Sample Collection	- 5 ml peripheral blood collected.
Hematological Analysis	- RBCs, Hb, WBCs, PLTs measured using Swe Lab Alfa Plus complete blood count machine.
Biochemical Tests	- ALT, AST, ALP tested using COBAS INTEGRA 400 PLUS auto-analyzer.
Erythropoietin (EPO)	- Measured using ELISA (DE3646) sandwich technique.

DNA Extraction	- Performed using PureLink® 96 Genomic DNA Kit (USA)- DNA quantified by NanoDrop™ (Thermo Scientific, USA).
JAK2 V617F Mutation Test	- Performed on all participants using real-time PCR.

2.2 Sample and data collection

An overall 5 ml of peripheral blood taken from both patient and control individuals, through venipuncture. The samples were obtained and then collected in vacutainer tubes, with and without anticoagulant. The collected samples without anticoagulant were centrifuged at 6000 rpm for 10 minutes at room temperature. The obtained serum samples either utilized right away for biochemical and EPO tests or stored in a freezer until they could be further analyzed. The blood samples containing the anticoagulant K2EDTA (5.4 mg) were utilized for both DNA extraction and hematological analysis. Then, gene mutation was examined for JAK II V617F through the utilization of real time PCR technique.

2.3 Assessing laboratory biomarkers

2.3.1. Hematological parameters

Samples of blood with anticoagulant inside the EDTA tube used for detection of hematological parameters such as Hemoglobin (HGB), white blood cell counts (WBC) and platelet counts (PLT) through the utilization of complete blood count machine (Swe lab Alfa Plus machine).

2.3.2. Liver function tests and Erythropoietin

The obtained serum samples used for tests of liver function (ALT, AST and ALP) by COBASS INTERGA 400 PLUS fully automated machine. Erythropoietin was detected via ELISA DE3646 machine. The sandwich enzyme-linked immunosorbent assay (ELISA) technique was used for measuring EPO that were used throughout the work. The ELISA plate is designated or mapped well. After adding sample and standard to the well, the procedure was continued as the

protocol (Demditec EPO ELISA DE3646). The normal range for the tests showed in table 1.

Table 2. Liver function tests.

Test name	Units	Reference range
ALT	IU/L	Male: Up to 50 Female: Up to 35
AST	IU/L	Male: Up to 50 Female: Up to 35
ALP	IU/L	Male: 40-129 Female: 35-104 Child: <187
EPO	mU/mL	3.2 - 31.9

2.3.3. Realtime PCR for Jack2

The blood samples were subjected to analysis for detection of JAK2 V617F. The gene mutation in myeloproliferative neoplasm (MPN) was examined for JAK II V617F through the utilization of real time PCR technique. The occurrence of this mutation was documented in the Philadelphia negative chromosome myeloproliferative neoplasms patients who participated in this study (4). The same procedure was used for the healthy controls. The DNA was extracted using a spin column method (PureLink® 96 Genomic DNA Kit, USA), depending on the manufacturer's instructions. Then for each sample, the concentration and purity of genomic DNA extraction determined using Nano-Drop™ (Thermo Scientific, USA) spectrophotometer. The recorded concentrations ranged from 22-100.29 ng/μl and the purity ranged 1.68–1.88.

Name of oligo	Sequence
Forward primer	TCCTCAGAACGTTGATGGCAG
Reverse primer	ATTGCTTTCCTTTTTCACAAGAT

2.4. Statistical analysis

For statistical analysis, GraphPad Prism 8 was used. First, the data was added to an excel file. Then, the data was arranged according to the cases, age, gender, and other parameters. For the continuous data Mann Whitney test was used and the data in the tables is represented as Medium (Minimum-Maximum). After that, Chi-square test was used to find the difference between the categorical variables that are represented also by percentage for further clarity. Then, Spearman correlation test was used to find correlation of age with EPO, hematological parameters, and liver enzymes. P value of less than 0.05 was considered significant throughout the paper.

3. Results

3.1 General Characteristics

In the study the 227 patients diagnosed with polycythemia vera and 32 healthy controls were enrolled. The median age of the patients and the controls nearly the same with non-significant difference (P value 0.091) which is 59 years and 56 years, respectively. However, the male was prominent among the patients, but the difference with the controls was nonsignificant (P value 0.431). JAK2 mutation was present in 94% of the patients, while all controls were JAK2-negative, a highly significant finding ($p < 0.0001$). Splenomegaly was observed in 158 patients (69.6%). Bone marrow biopsy showed that 218 (96%) patients have panmyelosis. myelofibrosis (9%) and thrombosis (8) were reported among the patients (table 2).

Table 3. The general characteristics of the participants.

	Patients n=227	Controls n= 32	P value
Age , median (range)	59 (25-88)	56 (15-81)	0.091
Gender (Male:Female)	143 (63%):84 (37%)	23 (72%):9 (28%)	0.431
JAK2 +/-	213 (94%)/14 (6%)	0 (0.0%)/32 (100%)	<0.0001 ****

Splenomegaly Yes/No	158/69		
Bone marrow biopsy			
Panmyelosis Yes/No	218 (96%)/9 (4%)		
Complications			
AML	8 (4%)		
MF	20 (9%)		
Thrombosis	19 (8%)		
Absence	180 (79%)		

Median (Minimum-Maximum) was used for age. Mann Whitney test for age and Fisher's exact test for gender and JACK2. AML; Acute myeloid leukemia, MF; myelofibrosis.

3.2. Hematological Parameters

The hematological parameters showed (Figure 1) high levels among the patients. WBC count was $12.40 \times 10^9/L$ and Hb levels were 17.7 (g/dL) that were significantly higher ($P < 0.0001$, both) compare to the control group ($9.85 \times 10^9/L$ and 14.2 g/dL, respectively). Moreover, RBC count significantly higher ($P 0.0008$) among the PV group ($5.7 \times 10^{12}/L$) compare to control group ($5.07 \times 10^{12}/L$).

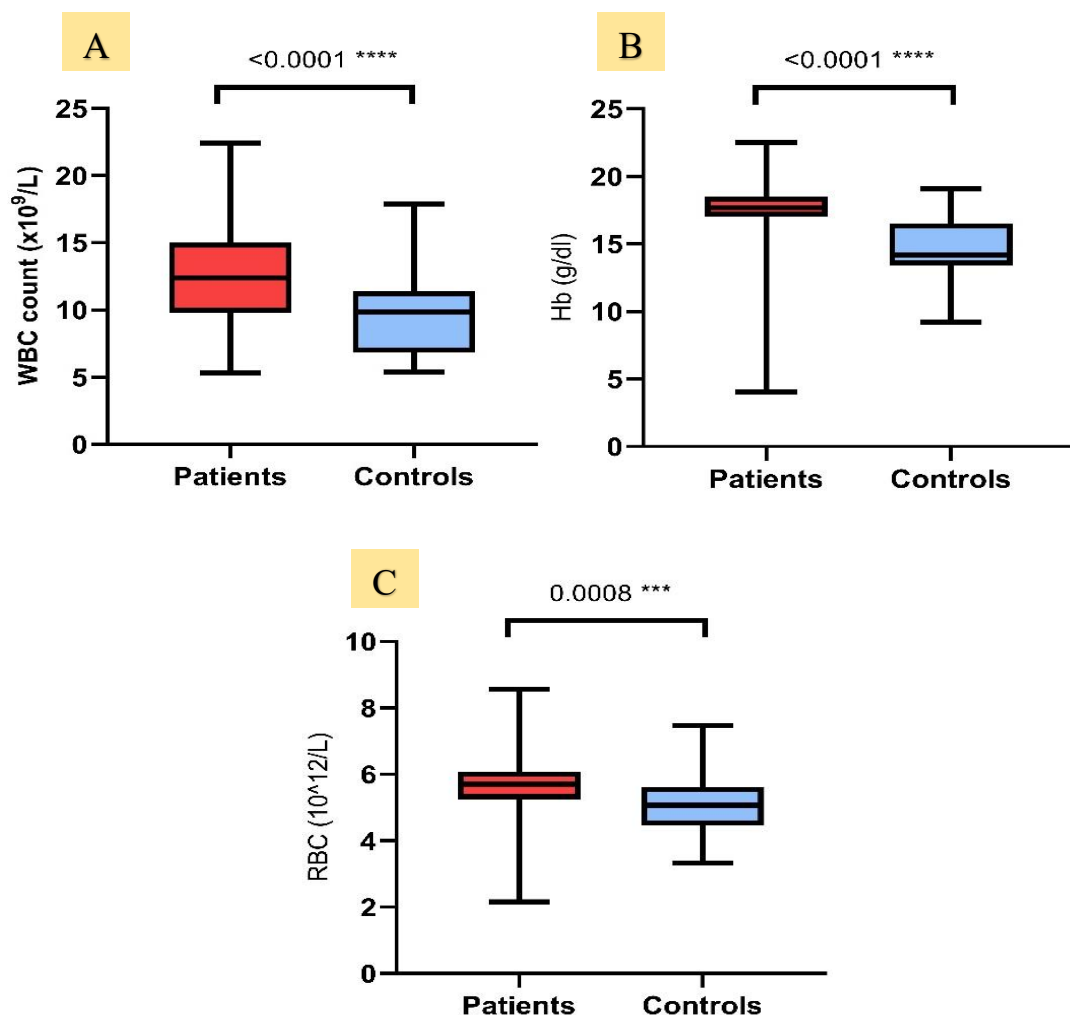


Figure 1. The comparison of hematological parameters between the patients and controls. A, B, and C. All parameters were significantly higher in PV patients compared to controls (P value < 0.05 for all comparisons). The data represented by Median (Minimum-Maximum). Mann Whitney test.

3.3. Erythropoietin and Liver Enzymes

Table 3 showed that there was no difference between The PV patients and Controls in comparison to AST and ALP with P value of 0.832 and 0.766, respectively. However, small but significant difference was observed in ALT (P value 0.034). In addition, EPO level decreased significantly (P value 0.0002) in PV patients as compare to the healthy controls.

Table 4. The comparison of EPO and the levels of liver enzymes between the patients and controls.

Parameters	Patients n=227	Controls n= 32	P value
ALT(U/L)	17 (3-353)	20 (4.5-91.6)	0.034 *
AST(U/L)	25.3 (8-65)	19.7 (13.7-138)	0.832
ALP(U/L)	88 (33-172)	89 (39-189)	0.766
EPO (mIU/ml)	3.9 (1-39.1)	11.5 (4.1-19.2)	0.0002 ***

The data represented by Median (Minimum-Maximum). Mann Whitney test

3.4. Correlation with age

The correlation as shown in table 4 showed that age did not significantly correlate with Hb, RBC, and EPO levels with P value more than 0.3 for all. However, the negative and significant correlation was observed for ALP (P value 0.022) in which by increasing age the ALP level decreases ($r = -0.22$). moreover, ALT and AST showed no significant age-related changes.

Table 5. Correlation of age with EPO, hematological parameters, and liver enzymes among the patients.

		Hb	RBC	EPO
Age	r	0.063	0.002	-0.091
	p-value	0.346	0.98	0.37
		ALT	AST	ALP
Age	r	-0.054	-0.049	-0.22
	p-value	0.584	0.618	0.022 *

Spearman correlation test. (*) Statistically significant difference ($p < 0.05$)

3.5. Liver Enzymes and Gender

When comparing liver enzyme levels between male and female PV patients, no statistically significant differences were found in ALT, AST, or ALP values (P value > 0.82, 0.22, and 0.83, respectively) as shown in (table 5).

Table 5. Comparison of liver function tests regarding the gender of the patients.

Parameters	Male n=143	Female n=84	P value
ALT(U/L)	17 (3-353.2)	16 (3.7-51)	0.82
AST(U/L)	24.89 (8-65)	26.8 (9-65)	0.22
ALP(U/L)	92 (33-172)	88 (31-168)	0.835

The data represented by Median (Minimum-Maximum). Mann Whitney test.

4. Discussion

Our study examined key characteristics of polycythemia vera (PV) by comparing 227 patients with 32 healthy controls. A particularly notable finding was that 94% of PV patients carried the JAK2 mutation—a well-established genetic hallmark of the disease—whereas none of the healthy individuals tested positive. This highlights the critical role of JAK2 mutation analysis in confirming a PV diagnosis and supports its inclusion as a standard component of diagnostic workups in clinical practice (13). We also observed that approximately 70% of patients presented with splenomegaly, and 96% demonstrated panmyelosis, characterized by increased production of all major blood cell lines in the bone marrow. These findings are consistent with the hyperproliferative nature of polycythemia vera and underscore the central role of clonal myeloproliferation in disease pathology. Notably, complications such as myelofibrosis and thrombotic events were relatively frequent in this cohort, aligning with previous reports and emphasizing the importance of vigilant long-term monitoring and early intervention to mitigate disease progression and associated risks (14).

Regarding laboratory findings, the differences between groups were pronounced. Patients with polycythemia vera exhibited significantly elevated red and white blood cell counts, consistent with the classical clinical features of the disease, including increased blood viscosity. Notably, erythropoietin (EPO) levels were markedly low among PV patients. This observation aligns with the established pathophysiology whereby clonal hematopoietic cells proliferate independently of normal regulatory signals such as EPO, primarily driven by the presence of the JAK2 mutation (15). The absence of significant correlations between age and hemoglobin (Hb), red blood cell count (RBC), or erythropoietin (EPO) levels in this Polycythemia Vera (PV) cohort highlights the disease's unique pathophysiology (16). PV disrupts normal hematological regulation through JAK2 mutation-driven clonal expansion, causing pathological erythrocytosis that operates independently of both age and physiological EPO signaling (characteristically suppressed in PV). While these hematological parameters show no age-dependence, hepatic involvement remains clinically critical.

Extramedullary hematopoiesis frequently leads to splenomegaly and may cause hepatic complications like portal hypertension or Budd-Chiari syndrome due to splanchnic vein thrombosis, necessitating vigilant monitoring alongside hematological indices (17). Liver function tests didn't show major differences between groups, though PV patients had slightly higher ALT levels. This could point to mild liver stress, but it doesn't appear to be a major concern in PV. We also noticed that older patients tended to have lower ALP levels. While this isn't fully understood, it might be related to age-related changes in bone or liver function—and it's worth exploring further. Men made up 63% of the PV group, which is consistent with other studies. However, gender didn't seem to affect liver enzyme levels, suggesting both men and women experience similar impacts from PV in that regard (18). That said, our study had a few limitations. The control group was relatively small, and since this was a cross-sectional study, it only captures a single point in time. Long-term studies could help reveal how trends like the age-ALP link develop over the years or whether mild ALT changes have clinical significance.

5. Conclusion:

To sum up, this study offers a solid overview of PV: nearly all patients had the JAK2 mutation, blood counts were elevated, and EPO levels were unusually low. Liver function didn't appear to play a major role, but the connection between age and ALP levels raises some intriguing questions. These results reinforce the value of JAK2 testing and routine blood work in managing PV. Looking ahead, future research especially studies involving larger and more diverse groups could help clarify how aging affects ALP and whether subtle liver changes have any long-term impact. For now, our findings add another valuable piece to the larger puzzle of understanding and treating PV.

Acknowledgement

We would like to express our gratitude to the Private Biolab and Nanakaly hospital for its support in this study.

Funding

None

Author contributions

The authors have contributed equally in conducting the research.

Conflict of interest

None

Ethical committee and consent for participation

The research project (June 5, 2024) has been approved by the ethical committee of Koya University-Erbil, meeting the Helsinki Declaration criteria. Each patient is required to sign a consent form before joining the study, and if they have any disabilities, we have asked their legal representatives to sign on their behalf.

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دیاریکردنی کاریگه‌ری نه‌خۆشی پۆلی سایثیمیا قی‌را له‌سه‌ر پارامیته‌ره‌کانی خوین و کاری ئەنزیمه‌کانی جگه‌ر له‌ نه‌خۆشه‌کانی پۆلی سایثیمیا قی‌را

پوخته:

پۆلی سایثیمیا قی‌را (PV) شێره‌نجه‌یه‌کی مایلوپرولیفیتراتیفه که تایبه‌تمه‌نده به زۆربوونی ژماره‌ی خرۆکه سووره‌کانی خوین و بازدانی جینی JAK2. ئەم توێژینه‌وه‌یه به‌راورد ده‌کات له‌ نێوان نه‌خۆشانی PV و کۆنتروڵدا له‌پۆی پارامیته‌ره‌کانی کلینیکی و پارامیته‌ره‌کانی خوین بۆ دیاریکردنی تایبه‌تمه‌ندییه تایبه‌ته‌کانی نه‌خۆشییه‌که. شیکارییه‌کی ئاماری گشتگیرمان ئەنجامداوه به‌کارهێنانی ئەو زانیاریانه‌ی له 227 کەس که به پۆلی سائیمیا قی‌را (PV) ده‌ستنیشانکراون و 32 کەسی ته‌ندروست. به‌راوردکردنه‌که کۆمه‌ڵیک گۆراوه‌ی وه‌ک تایبه‌تمه‌ندییه دیموگرافیه‌کان، دۆخی گۆرانی JAK2 V617F، و پێوه‌ره سه‌ره‌کییه‌کانی خوین له‌خۆگرتبوو- ئەوانیش ژماره‌ی خرۆکه سووره‌کانی خوین (RBC)، ئاستی هیموگلوبین (Hb)، ژماره‌ی خرۆکه سپیه‌کان (WBC) و ژماره‌ی په‌ره‌خانه‌کان (PLT). سه‌ره‌پای ئەوه، نیشانه‌ره‌کانی کارکردنی جگه‌ر، له‌وانه‌ش ئەلکه‌لین فوسفاته‌یز (ALP)، ئەسپه‌رتییت ئەمینوترانسفیریز (AST)، و ئاستی ئیترتروپۆیتین (EPO). گۆرانکارییه‌کانی JAK2 له 94% ی نه‌خۆشه‌کاندا هه‌بوون ($p < 0.0001$). نه‌خۆشانی PV ژماره‌ی هیموگلوبین، WBC، و RBC زۆر به‌رزبووبۆوه ($p < 0.001$)، به‌لام ئاستی ئیترتروپۆیتین به‌شیوه‌یه‌کی به‌رچاو که‌متر بوو ($p = 0.0002$). ته‌مه‌ن په‌یه‌ه‌ندییه‌کی نه‌رێنی له‌گه‌ڵ ALP هه‌بوو ($p = 0.022$)، له‌کاتی‌که‌دا گه‌وره‌بوونی سپل (69.6%) و پانمایلوئیس (96%) له‌ زۆربه‌ی نه‌خۆشه‌کان هه‌بوون. ئەنزیمه‌کانی جگه‌ر هه‌روه‌ها په‌گه‌ز هه‌یج په‌یه‌ه‌ندییه‌کی به‌رچاویان نیشان نه‌دا. PV ایبه‌تمه‌نده به‌ گۆرانکارییه‌کانی جینی JAK2، به‌رزبوونه‌وه‌ی به‌ره‌مه‌یانی خانه‌کانی خوین، و که‌مبوونی ئیترتروپۆیتین. گۆرانکاری له‌ ئاستی ALP له‌گه‌ڵ ته‌مه‌ن و که‌مترین به‌شداریکردنی جگه‌ر تیروانینیکی نوێ پێشکه‌ش ده‌کات، که تیشک ده‌خاته سه‌ر گرنگی پشکنینی JAK2 و چاودێریکردنی به‌رده‌وامی خوین بۆ ده‌ستنیشانکردنی ورد و به‌رپه‌وه‌ردنی کاریگه‌ر.

التعرف على تأثير بولى سايثيميا فيرا الحقيقية على المعايير الدموية ووظيفة إنزيمات الكبد لدى مرضى بولى سايثيميا فيرا

الملخص:

بولى سايثيميا فيرا (PV) هي ورم تكاثري نقبي يتميز بكثرة كريات الدم الحمراء والطفرة في جين (JAK2). تقوم هذه الدراسة بمقارنة مرضى (PV) وضوابط الأصحاء لتحديد السمات الخاصة بالمرض. وتم إجراء تحليل إحصائي شامل باستخدام البيانات التي تم جمعها من (227) شخصاً بحيث تم تشخيصهم بمتلازمة تعدد السكري الحقيقي (PV) و (32) من الأشخاص الأصحاء. كما و شملت المقارنة عدداً من المتغيرات مثل الخصائص الديموغرافية وحالة طفرة (JAK2 V617F) والمعايير الدموية الرئيسية – والتي هي عدد خلايا الدم الحمراء (RBC) ومستوى الهيموجلوبين (Hb) وعدد خلايا الدم البيضاء (WBC) وعدد الصفائح الدموية (PLT). بالإضافة إلى ذلك، تم تقييم علامات وظائف الكبد، بما في ذلك مستويات الكالين الفوسفاتيز (ALP)، وأسبارتات أمينوترانسفيراز (AST)، وإريثروبويتين (EPO)، لتقييم المشاركة الجهازية المحتملة. وكانت طفرات (JAK2) موجودة في 94٪ من المرضى ($p < 0.0001$). وأظهرت مرضى PV ارتفاعاً في الهيموجلوبين، وعدد خلايا الدم البيضاء وخلايا الدم الحمراء ($p < 0.001$) مع مستويات إريثروبويتين أقل بشكل ملحوظ ($p = 0.0002$). كان العمر مرتبطاً سلباً بـ ALP ($p = 0.022$)، في حين كان تضخم الطحال شائع بنسبة (69.6٪) وتضخم النخاع العظمي كان شائعاً بنسبة (96٪). ولم تظهر إنزيمات الكبد وكذلك الجنس أي ارتباط كبير. يتميز (PV) بطفرة (JAK2) وارتفاع إنتاج خلايا الدم وقمع الإريثروبويتين. تقدم التغيرات في مستويات (ALP) مع التقدم في السن والحد الأدنى من إصابة الكبد رؤى جديدة، مما يسلط الضوء على أهمية اختبار (JAK2) ومراقبة الدم بانتظام من أجل التشخيص الدقيق والإدارة الفعالة.