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Evaluation of hematological profile variations in pregnant women: An indicator of early pregnancy loss

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Abstract

Pregnancy is a physiological state characterized by significant systemic and hematological changes that are necessary to support fetal development. While these changes are typically adaptive, they can sometimes lead to complications or become markers of underlying issues, especially following miscarriage. This study aimed to evaluate and compare hematological parameters in pregnant women and women who experienced miscarriage, to better understand physiological changes and potential deviations. An experimental study was conducted involving 100 females aged 18-42 years, divided into two groups: Group I (50 pregnant women) and Group II (50 women post-miscarriage). Blood samples were examined to assess the complete blood count (CBC) and hematological indices including Hemoglobin (Hb), counts of red and white blood cells (RBCs and WBCs), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC), and differential leukocyte count. Statistical analysis revealed a significant decrease in Hb and RBC counts post-miscarriage ($p < 0.05$), whereas WBC levels were notably elevated ($p \leq 0.03$). Variability in MCV, MCH, and MCHC values was observed ($p < 0.05$). Neutrophil counts increased significantly, while platelet counts, monocytes, eosinophils, and lymphocytes showed marked reductions ($p < 0.02$). This study highlights distinct hematological changes during pregnancy and after miscarriage. Regular monitoring of hematological parameters is essential during pregnancy for early detection of abnormalities. Nutritional support and clinical follow-up are recommended to ensure maternal health and fetal development.

Introduction

Pregnancy is a dynamic physiological state in which a fertilized ovum develops into a complete fetus. Although it is a natural biological process, it triggers a cascade of systemic changes within the maternal body, including hormonal, hematological, and metabolic adaptations to support fetal development and maintain maternal health [1]. Among these, hematological changes are particularly important, as they are essential for oxygen transport, immune defense, and maintaining hemostasis throughout gestation. Core hematological indicators such as hemoglobin (Hb), hematocrit (HCT), total red blood cell (RBC) and white blood cell (WBC) counts, along with mean corpuscular volume (MCV) and platelet count, often shift significantly as pregnancy progresses and can serve as markers for maternal well-being [2].

Miscarriage, which refers to the unplanned loss of pregnancy before the 24th week of gestation, is among the common complications encountered during early pregnancy. It remains a common complication, affecting approximately 15–20% of clinically recognized pregnancies [3]. Miscarriage not only poses physiological risks but also causes emotional and psychological distress, including anxiety, depression, and in some cases, post-traumatic stress [4]. A specific type of miscarriage, known as missed abortion, involves intrauterine fetal demise without the immediate expulsion of gestational tissue. Contributing factors include chromosomal abnormalities, hormonal imbalances, uterine defects, infections, and coagulation disorders such as thrombophilia [5].

Hematological adaptations begin as early as the first trimester, typically around the sixth week of gestation, and often persist into the postpartum period. These include plasma volume expansion, mild leukocytosis, increased RBC mass, and a hypercoagulable state, all of which are essential for meeting the increased metabolic demands of pregnancy [6]. However, when dysregulated, these changes can lead to clinical conditions such as anemia, thrombocytopenia, or excessive clotting. Anemia remains the most prevalent hematological disorder in pregnancy, with recent global data indicating that approximately 36% of pregnant women are affected, contributing significantly to maternal morbidity and mortality [7].

Moreover, several maternal factors have been tied to a greater risk of losing the pregnancy in its early weeks. Maternal age beyond the optimal range and excessive body mass index, endocrine disorders, and environmental exposures such as smoking, alcohol intake, and high caffeine consumption have all been associated with miscarriage risk [8]. Additionally, vaginal bleeding in early pregnancy, a common presentation in about one-quarter of cases, can be a warning sign of impending pregnancy loss and necessitates careful hematological and obstetric evaluation [9].

Given the pivotal role of hematological stability in ensuring positive pregnancy outcomes, the present study seeks to evaluate and compare hematological profiles in women with viable pregnancies and those who have experienced miscarriage. This analysis aims to identify significant hematological alterations that may contribute to or predict early pregnancy loss, thereby offering insights into preventive care and clinical decision-making.

Materials and Methods

Study design

This experimental research was carried out over six months, from February to July 2023, at the Pathology Research Laboratory, Riphah International University, Lahore Campus, Lahore, Pakistan. The study was conducted in collaboration with the gynecology departments of public sector hospitals located in Faisalabad. Before initiating the research, ethical clearance was secured from the Institutional Research Ethics Committee of Riphah International University (Reference No. REC/RCR & AHS/22/0911). Informed written consent was obtained from all individuals who agreed to participate in the study.

Study population

The study enrolled 100 women, aged between 18 and 42 years, who were divided into two distinct groups. Group 1 comprised 50 women with viable pregnancies during the first trimester, whereas Group 2 consisted of 50 women who had suffered early pregnancy loss.

Inclusion and exclusion criteria

Participants included pregnant women appearing medically healthy during their first trimester and women who had recently experienced a miscarriage, without any known infectious diseases. Women

diagnosed with infectious diseases such as hepatitis were excluded from the study.

Data collection

Data were collected using a structured questionnaire that gathered demographic and clinical information. This included participants' age, weight, and body mass index (BMI), as well as details about their lifestyle, dietary habits, and medication use. Stress levels and general health status were also recorded, as well as any history of previous pregnancy loss or related complications. From each participant, 5 mL of venous blood was collected using sterile disposable syringes. The blood samples were transferred into ethylenediaminetetraacetic acid (EDTA) tubes for hematological analysis and were properly labeled with the participant's name, age, and laboratory ID.

Hematological analysis

Hematological assessments were performed using an automated analyzer (Mindray BC-6000, manufactured by Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China). The evaluated parameters included hemoglobin (Hb), red and white blood cell counts (RBC and WBC), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), platelet count, as well as differential counts of neutrophils, lymphocytes, monocytes, eosinophils, and basophils.

β-hCG assay

Serum β-hCG levels were assessed only in Group 2 (miscarriage cases). The biochemical analyses were carried out using the Cobas 6000 automated analyzer from Roche Diagnostics, Basel, Switzerland. Standard laboratory protocols were followed during analysis.

Statistical analysis

For hematological testing, 25 µL of anticoagulated blood was utilized. All data were compiled and statistically analyzed to compare the two groups. Data were presented as mean ± standard deviation (SD). Statistical comparisons between the two groups were performed using an independent t-test, with a p-value below 0.05 regarded as indicative of statistical significance.

Results

In this study, 100 pregnant women were studied with ages ranging from 21-42 years (**Fig. 1**). These 100 women were divided into two groups: one whose pregnancy continued and the other who experienced miscarriage before the 13th week of pregnancy. Each group contained 50 participants who were examined for hematological parameters. Results were grouped according to the trimester and miscarriage.

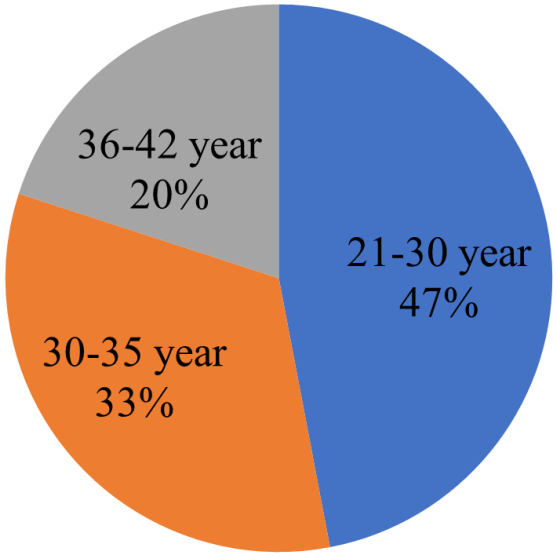

Fig. 1: Age distribution of participants

Hematological parameters of study groups

In the present study, a comparative analysis was conducted between pregnant women in the first trimester (control group) and women who experienced miscarriage. The control group exhibited significantly higher mean values of hemoglobin (12.01 g/dL) and red blood cell count (4.37×10^{12}/L) compared to the miscarriage group, where these parameters dropped to 9.4 g/dL and 4.01×10^{12}/L, respectively. Hematocrit levels followed a similar trend, with the control group showing a mean of 36.7%, which decreased to 30.8% in the miscarriage group. MCV, MCH, and MCHC indicators of red blood cell size and hemoglobin content were also notably reduced in the miscarriage group, with average values of 77.9 fL, 23.5 pg, and 29.9 g/dL, respectively, compared to the control group's 82.1 fL, 27.2 pg, and 32.6 g/dL. Leukocyte analysis revealed elevated white blood cell (WBC) and neutrophil counts in the miscarriage group ($9.47 \pm 2.89 \times 10^9$/L and 72.46 ± 8.70%, respectively),

indicating a potential inflammatory response or immune activation. Conversely, the control group showed higher values of lymphocytes (P = 0.02), monocytes, and eosinophils, though the latter two did not reach statistical significance. Platelet counts were slightly reduced in the miscarriage group (287 × 10^9/L) compared to the control group (297 × 10^9/L). Collectively, these findings suggest that hematological profiles, particularly involving hemoglobin, erythrocyte indices, and leukocyte differentials, undergo significant alterations following miscarriage and may serve as potential indicators of maternal physiological changes post-pregnancy loss.

Comparison of hematological parameters

When the mean values of hematological parameters of pregnant females were compared, it was observed that Hb and RBC values were reduced while WBC values increased. Hematocrit was increased in the control group but gradually decreased in the miscarriage group. The mean value of MCV was higher in the control group but lower in the miscarriage group. MCH was also decreased in the miscarriage group, but MCHC was slightly decreased after miscarriage. A slight decrease in the mean value of platelets was observed in the miscarriage group. Only neutrophils were higher in the miscarriage group, but the values of monocytes, lymphocytes, and eosinophils were lower compared to the control group.

In the Control group, the value of WBC Count, Neutrophils, Lymphocytes, Monocytes, and Eosinophils are (8.8 x10^9/l), (65.5%), (27.0%), (4.4%), (2.3%), respectively. In the miscarriage group, the value of WBC Count (Total), Neutrophils, Lymphocytes, Monocytes, and Eosinophils are (9.4 x$10^{\wedge 9}$/l), (72.5%), (20.7%), (4.3%), (2.1%) respectively (**Table 1**).

Table 1: Comparison of hematological parameters between the continued pregnancies and the miscarriage groups

Sr #	CBC Parameters	Control group Mean ± SD	Miscarriage group Mean ± SD	*P* Value
1	Hb g/dl	12.0±3.4	9.4±1.40	0.045*
2	RBC x10^12/l	4.37±1.35	4.01± 0.69	0.037*
3	WBC (Total) x10^9/l	8.88±3.2	9.49± 2.89	0.103
4	HCT %	36.7±5	30.8± 4.86	0.044*
5	MCV fl	82.1±8.60	77.9± 10.72	0.012*
6	MCH pg	27± 3.45	24±3.79	0.034*
7	MCHC g/dl	33± 3.41	30±3.23	0.010*
8	Platelets x10^9/l	297±110	287±80	0.009*
9	Neutrophils (%)	66.5±7.3	72.4± 8.70	0.012*
10	Lymphocytes (%)	27.0±5	20.7± 7.61	0.026*
11	Monocytes (%)	4.44±2	4.36±2.1	0.863
12	Eosinophils (%)	2.3±2	2.1±1.40	0.322

*Results were considered significant with *P* value <0.05.

Hb (Hemoglobin), RBC (Red Blood Cells), WBC (White Blood Cells), HCT (Hematocrit) MCV (Mean corpuscular Volume) MCH (Mean corpuscular Hemoglobin), MCHC (Mean corpuscular Hemoglobin Concentration).

β-hCG levels

β-hCG level was compared between the continued pregnancies and failed pregnancies of gestational age up to 13 weeks. The analysis of serum beta-hCG levels revealed a marked difference between continued and failed pregnancies. In cases of continued pregnancies, the mean beta-hCG concentration was 77,314.36 IU/L, with a standard deviation of 128,164.34 IU/L (**Fig. 2**). In contrast, the mean beta-hCG level in failed pregnancies was significantly lower, measured at 4,728.4 IU/L with a standard deviation of 13,766.34 IU/L (**Table 2**). This substantial disparity underscores the clinical relevance of beta-hCG as a biomarker for early pregnancy viability. A t-test was performed to compare the mean beta-hCG levels between continued pregnancies and failed pregnancies.

Discussion

The core purpose of this investigation was to evaluate hematological differences between healthy early pregnancies and those ending in miscarriage. Hemoglobin (Hb) levels were notably reduced in

Table 2: Comparison of the beta-hCG levels of study groups

	Continued Pregnancies Beta-hCG (IU/L)	Failed Pregnancies Beta-hCG (IU/L)	*P* value
Mean	77314	4728.4	0.000
Std. Deviation	128164.34	13766.34	

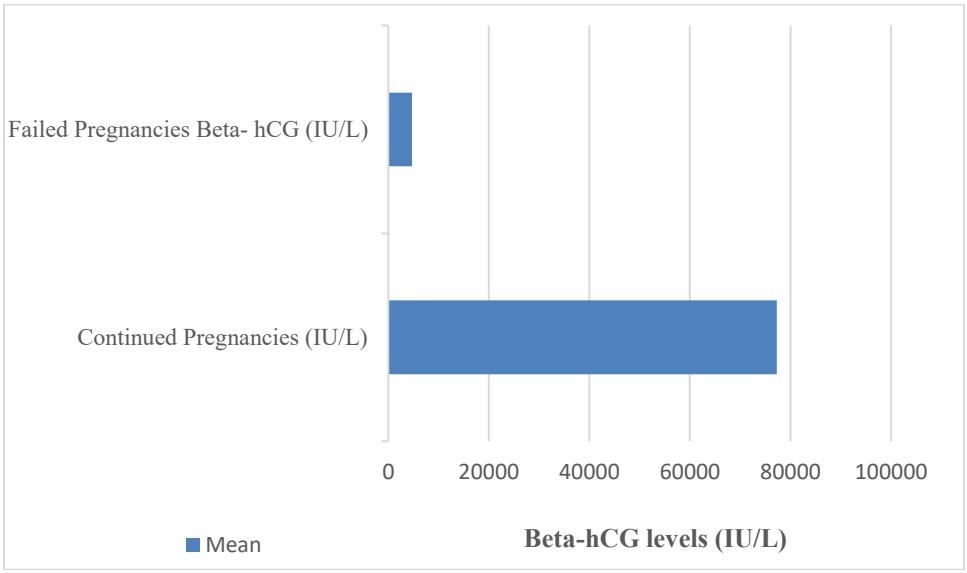

Fig. 2: Comparison of the mean beta-hCG levels between continued pregnancies and failed pregnancies

women who experienced miscarriage (mean: 9.41 g/dL) compared to those in their first trimester of a continued pregnancy (mean: 12.01 g/dL). This decline is consistent with findings that during normal pregnancy, hemodilution due to plasma volume expansion leads to a relative reduction in hemoglobin levels [10]. However, the further reduction in Hb after miscarriage may reflect acute physiological changes or blood loss associated with the event.

Red blood cell (RBC) counts followed a similar trend, with a mean of 4.376×10^{12}/L in continued pregnancies and 4.011×10^{12}/L after miscarriage. The decrease in RBCs post-miscarriage may indicate suppressed erythropoiesis or blood loss, findings supported by recent data suggesting lower RBC indices in early pregnancy loss [11]. A statistically WBC counts differed significantly between the groups which were higher after miscarriage (mean: 9.476×10^9/L) than during pregnancy (mean: 8.882×10^9/L). This elevation may reflect systemic inflammatory response or tissue resorption processes, similar to the reports linking miscarriage with leukocytosis and elevated inflammatory markers [12].

Neutrophil percentages also increased substantially after miscarriage (72.4%) compared to the first trimester (66.5%). This aligns with the role of neutrophils in early immune defense and their upregulation during pregnancy-related complications [13]. Increased neutrophilic activity has also been linked to fetal rejection responses and inflammation-driven miscarriage events [14].Hematocrit levels in this study declined from 36.78% in the first trimester to 30.88% after miscarriage. This pattern suggests possible volume depletion or hemorrhagic loss, consistent with findings from recent cohort studies evaluating post-miscarriage hematological recovery [15].Platelet counts in both groups were relatively stable, with a slight decrease observed post-miscarriage (297.26×10^9/L vs. 287.82×10^9/L), and no statistically significant difference. These results align with those of Odo C, et al, who observed minimal changes in platelet levels during uncomplicated pregnancies and post-loss phases.

The mean corpuscular volume (MCV) was higher during pregnancy (82.16 fL) and slightly lower after miscarriage (77.98 fL) [16]. This reduction could indicate a shift toward microcytic erythrocyte production following miscarriage, potentially due to iron depletion or altered erythropoiesis [17]. In contrast, mean corpuscular hemoglobin (MCH) and

mean corpuscular hemoglobin concentration (MCHC) both declined after miscarriage (MCH: 26.75 pg to 23.71 pg; MCHC: 32.72 g/dL to 30.58 g/dL), mirroring similar declines reported in recent work on anemia profiles associated with pregnancy complications [18]. Slight fluctuations in monocyte counts were noted (4.44% in the first trimester vs. 4.36% post-miscarriage). The modest drop may reflect monocyte-mediated immune regulation following fetal loss. However, monocyte behavior in early pregnancy loss is still debated, with recent research showing both increases and decreases depending on the timing and cause of miscarriage [19]. Eosinophil counts were reduced post-miscarriage (2.52% to 1.97%), which may reflect immune redirection or stress-related eosinopenia, in line with immunological shifts noted by [20].Finally, lymphocyte levels showed a significant decline after miscarriage (from 27.00% to 20.78%), likely due to a shift toward innate immune activation and suppression of adaptive immunity post-loss. Studies have shown that lymphocyte activity, particularly regulatory T-cell function, plays a critical role in maintaining fetal tolerance, and their reduction may contribute to miscarriage [21, 22].

This study confirmed that mean β-hCG levels were significantly higher in continued pregnancies compared to failed pregnancies at ≤13 weeks of gestation ($p < 0.001$), supporting its potential application as an early marker of pregnancy viability. Previous research [23]aligns with our findings that demonstrated β-hCG levels below 69,636 mIU/mL at week 7 correlated with a higher risk of first-trimester pregnancy loss, [24]while identified a prognostic cutoff near 88,000 IU/L in IVF pregnancies. Another study reported robust diagnostic performance of β-hCG in predicting early pregnancy outcomes in assisted conception cohorts[25]. Finally Hou L, et al, emphasized that plateauing or declining β-hCG trends during early gestation are strongly associated with non-viable pregnancies [26].

Conclusions

This study highlights significant differences in hematological parameters between healthy pregnancies and cases of miscarriage, providing valuable reference ranges for clinical assessment in early gestation. The observed changes in hemoglobin, RBC count, WBC count, and other hematological indices emphasize the importance of routine blood profiling for the early detection and management of pregnancy-related complications. These findings support the importanceof timely monitoring and nutritional interventions during pregnancy, especially in resource-limited settings. However, the study was limited by its sample size and single-center design, which may affect the generalizability of the results. Future research with larger, multi-center populations and longitudinal follow-up is recommended to validate these findings and further explore the underlying mechanisms contributing to hematological alterations in pregnancy and miscarriage. Additionally, strengthening prenatal education regarding balanced nutrition and regular health checkups can play a crucial role in improving maternal and fetal outcomes.

Ethical Statement and Participants' Consent

Ethical approval for this study was granted by the Institutional Research Ethics Committee of Riphah International University, Lahore, Pakistan (Reference No. REC/RCR & AHS/22/0911). Prior to participation, written informed consent was obtained from all individuals. All research procedures adhered to the ethical guidelines established by the university's ethics committee.

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Conflict of interest

The authors declare no conflict of interest.

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