Expectant Mothers with Iron Deficiency Anemia: Correlation Between Oxidative Stress, Erythrocyte Indicators, and Iron Stores

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KEYWORDS

Iron deficiency anemia, oxidative stress, malondialdehyde, serum ferritin, hematological indices..

ABSTRACT

Introduction: Iron deficiency anemia is a common condition in pregnant women, associated with adverse maternal and fetal outcomes. Oxidative stress, indicated by elevated malondialdehyde (MDA) levels, may exacerbate anemia by damaging red blood cells and impairing iron metabolism. This study aims to explore the relationship between oxidative stress, measured through serum MDA levels, and hematological indices, including hemoglobin and ferritin, in pregnant women diagnosed with iron deficiency anemia. By comparing these parameters with healthy pregnant and non-pregnant controls, we seek to enhance understanding of the mechanisms underlying anemia during pregnancy and identify potential targets for intervention.

Materials & Methods: The study included 75 women aged 20 to 40 years, comprising 25 cases of iron deficiency anemia during pregnancy, 25 healthy pregnant controls, and 25 healthy non-pregnant controls. Blood samples (10 ml) were collected for hemoglobin, MCH, MCHC, serum ferritin, and MDA analysis. Statistical analysis was performed using ANOVA and Pearson's correlation.

Results: MDA levels were significantly elevated in anemia cases (6.96 ± 1.69) compared to pregnant controls (4.63 ± 1.55) and healthy controls (3.65 ± 1.08), indicating increases of approximately 50.3% and 90.0%, respectively. Serum ferritin levels were markedly reduced in anemia cases (8.3 ± 7.94 ng/ml) compared to pregnant controls (39.10 ± 13.68 ng/ml) and healthy controls (61.05 ± 25.29 ng/ml). Hemoglobin, MCV, MCH, and MCHC were also significantly decreased in anemia cases compared to both control groups.

Discussion: The findings highlight a strong association between elevated oxidative stress, indicated by increased MDA levels, and reduced iron stores in iron deficiency anemia during pregnancy. This study underscores the importance of monitoring oxidative stress and iron levels to manage anemia effectively.

INTRODUCTION

Iron deficiency anemia (IDA) represents a significant global health challenge, particularly for pregnant women, with approximately 60% affected worldwide (1). This condition not only compromises maternal health but also poses severe risks for fetal development. IDA is associated with a range of adverse outcomes, including low birth weight, preterm delivery, and increased maternal mortality (2) (3). As pregnancy places increased iron demands on the body, understanding the mechanisms underlying IDA is essential for developing effective interventions.

Ferritin is a crucial protein responsible for storing and regulating iron in the body, serving as a key biomarker for assessing iron status. Low ferritin levels indicate depleted iron stores, which can worsen anemia and lead to further complications during pregnancy (4). In pregnant women, maintaining adequate ferritin levels is vital for ensuring that both the mother and fetus receive sufficient iron. This is particularly important as iron is a critical component of hemoglobin, necessary for oxygen transport in the bloodstream. Without adequate iron, the body struggles to produce healthy red blood cells, exacerbating the risk of IDA.

In addition to ferritin, oxidative stress plays a significant role in the pathophysiology of IDA. Oxidative stress occurs when there is an imbalance between the production of reactive oxygen species (ROS) and the body's ability to detoxify these harmful byproducts (5). One key marker of oxidative stress is malondialdehyde (MDA), a byproduct of lipid peroxidation that indicates cellular damage. Elevated MDA levels can indicate increased oxidative stress, which may further complicate IDA by damaging erythrocytes and impairing iron metabolism. This interplay between oxidative stress and iron deficiency is critical to understanding the full scope of IDA in pregnant women (3).

Research has shown that oxidative stress can lead to increased fragility of red blood cells, making them more susceptible to hemolysis (6). This damage can result in a decrease in circulating red blood cells, further exacerbating anemia. Additionally, oxidative stress may impair iron absorption in the intestines (7), compounding the challenges faced by pregnant women who already have

increased iron requirements. Therefore, the assessment of both ferritin and MDA levels provides valuable insights into the severity of IDA and the oxidative state of expectant mothers.

While the focus on ferritin and MDA is crucial, it is essential to consider broader factors that contribute to anemia in pregnant women. Nutritional deficiencies, such as inadequate intake of iron-rich foods, can significantly impact ferritin levels. Socioeconomic conditions, including access to healthcare and education about nutrition, also play a vital role in the prevalence of IDA. Addressing these factors through public health initiatives and targeted interventions can help reduce the incidence of anemia among expectant mothers.

MATERIALS AND METHODS

Study Population

The study was conducted among women attending the outpatient department (OPD) or admitted to the Obstetrics and Gynecology (OBG) department at Medical College Hospital. Participants included women aged 20 to 40 years who were in the second and third trimesters of pregnancy. The study comprised a total of 75 women: 25 cases diagnosed with iron deficiency anaemia during pregnancy, 25 healthy pregnant women (non-anaemic), and 25 healthy non-pregnant women serving as controls. This design allowed for a comparative analysis of the different groups. Women with chronic diseases, those who were habituated drinkers or smokers, and those experiencing complicated pregnancies were excluded from the study to ensure a homogeneous sample.

Sample Collection

Under strict aseptic precautions, a total of 10 ml of venous blood was collected from each participant. Of this total volume, 2 ml was utilized for the estimation of hemoglobin levels, mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). The remaining 8 ml of blood was allowed to clot, and serum was subsequently separated. Serum ferritin levels were assayed immediately after the serum separation, while malondialdehyde (MDA) levels were measured within two hours of sample collection. To ensure the integrity of the samples, the serum was stored at 4°C until the analysis of serum MDA was conducted.

Parameters Measured

The following parameters were measured in the study:

- **Serum MDA:** This is an indicator of lipid peroxidation and oxidative stress.
- **Serum Ferritin:** This serves as an indirect measure of the body's iron stores.
- **Hematological Indices:** Including hemoglobin (Hb), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). All hematological indices were analyzed using a cell counter machine, specifically the SYSMEX model.

All chemicals and reagents used for the assays were of analytical grade, ensuring the reliability and accuracy of the results.

Statistical Analysis

The statistical analysis of the data was carried out using the Analysis of Variance (ANOVA) test, which is appropriate for comparing means across multiple groups. Additionally, Pearson's correlation was employed to assess the relationship between various parameters measured in the study. Frequency and proportions were calculated to determine associations between different variables, providing a comprehensive overview of the findings. This rigorous statistical approach facilitated a robust analysis of the data obtained from the participants

Results

There was a notable increase in the mean levels of malondialdehyde (MDA) in the iron deficiency anaemia cases (6.96 ± 1.69) compared to the pregnant controls (4.63 ± 1.55), showing an increase of approximately 50.3%. Similarly, the levels were significantly higher than those in the healthy controls (3.65 ± 1.08), reflecting an increase of about 90.0%.

The mean serum ferritin levels in the cases were recorded at 8.3 ± 7.94 ng/ml, while the pregnant controls had a mean of 39.10 ± 13.68 ng/ml, indicating a decrease of approximately 78.8%. The healthy controls displayed higher levels at 61.05 ± 25.29 ng/ml, resulting in a decrease of around 86.4%, as illustrated in Table 1.

Regarding hemoglobin (Hb) percentages, the mean ± standard deviation in the cases was 7.45 ± 1.08 gm%, in the pregnant controls it was 11.62 ± 0.88 gm%, revealing a decrease of about 36.0%. In the non-pregnant controls, the mean was 12.44 ± 0.86 gm%, indicating a reduction of approximately 40.4%.

Furthermore, the mean ± SD values for mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) in the cases were 71.8 ± 8.05 fl, 22.01 ± 4.08 pg, and 30.83 ± 1.91 g/dl, respectively. In comparison, the pregnant controls showed mean values of 90.72 ± 3.33 fl, 28.77 ± 2.65 pg, and 33.03 ± 1.06 g/dl, reflecting decreases of approximately 20.8%, 23.4%, and 6.7%, respectively. The non-pregnant controls exhibited MCV, MCH, and MCHC values of 88.61 ± 3.81 fl, 30.44 ± 1.84 pg, and 33.55 ± 1.40 g/dl, resulting in decreases of about 19.0%, 27.8%, and 8.1%, respectively. Statistically significant reductions in Hb%, MCV, MCH, and MCHC values were observed in the cases when compared to both control groups, as depicted in Table 1.

TABLE-1

Parameter	Pregnancy With Anaemia (cases)	Healthy Pregnant Controls (non anaemic)	Healthy non pregnant Controls (non anaemic)	F	Sig
MDA in nmol/ml	6.96± 1.69	4.63 ± 1.55	3.65 ± 1.08	33.82	0.000
Serum ferritin ng/ml	8.30± 7.93	39.10 ± 13.68	61.05 ± 25.29	59.19	0.000
Hb(in gms/dL)	7.45 ± 1.08	11.62 ± 0.88	12.44 ± 0.86	200.349	0.000
MCV in fl	71.80 ± 8.05	90.72 ± 3.33	88.61 ± 3.81	89.244	0.000
MCH in pg	22.01 ± 4.08	28.77±2.65	30.44 ± 1.84	55.221	0.000
MCHC in gm/dl	30.83± 1.91	33.03± 1.06	33.55± 1.4	23.312	0.000

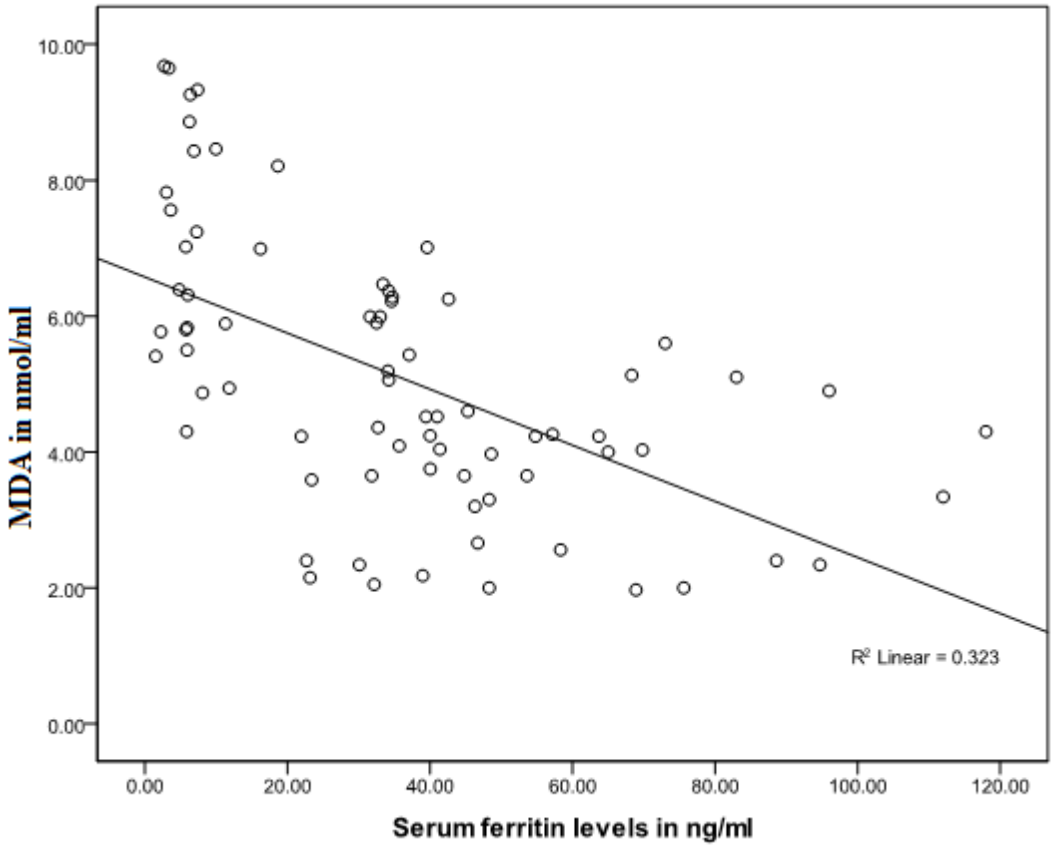
Pearson's correlation coefficient between lipid peroxidation and ferritin levels was observed .As tabulated in Table 2

TABLE 2

Parameter	Serum MDA(nmol/mL)	
	R	p
Serum Ferritin (ng/mL)	-0.568	0.000

A negative correlation were obtained when serum MDA was plotted against serum Ferritin.(Graph 1) with r-value of -0.568

SCATTERGRAM:MDA AND SERUM FERRITIN



There was a highly significant difference in serum ferritin levels and erythrocyte indices in all the three groups. The ferritin levels showed a negative correlation with MDA.

Discussion & Conclusion

The findings from this study underscore the significant biochemical and hematological alterations associated with iron deficiency anemia in pregnant women.

Iron deficiency anemia (IDA) in pregnancy is a significant public health concern due to its association with increased oxidative stress and adverse outcomes for both the mother and fetus. The observed increase in malondialdehyde (MDA) levels in the anemia cases (6.96 ± 1.69 nmol/ml) compared to healthy pregnant controls (4.63 ± 1.55 nmol/ml) and healthy non-pregnant controls (3.65 ± 1.08 nmol/ml) indicates heightened oxidative stress. This is consistent with findings that free radical generation and peroxidation of vital body molecules are prevalent in IDA, increasing the risk of complications during pregnancy. A similar study observed that decreased delivery of oxygen to RBC hemoglobin destabilized hemoglobin, which increased the rate of auto-oxidation and thus explains how anemia generates red cell oxidative stress. Our study showed a highly significant increase in oxidative stress in the anemic group (8). Furthermore, excessive auto-oxidation of hemoglobin in anemia can lead to increased methemoglobin and superoxide levels. Research indicates that low birth weight and the risk of preterm delivery increase by 10-40% in women with moderate to severe anemia. Preterm delivery is attributed to hypoxia, oxidative stress, and infection (9). Chronic hypoxia triggers a stress response, increasing cortisol production in the fetus and resulting in preterm delivery. The significant negative correlation coefficient observed between MDA levels and serum ferritin in our study indicates that oxidative stress plays a crucial role in IDA and thus in pregnancy outcomes.

Increased MDA levels indicate oxidative stress, which can damage red blood cell membranes, leading to decreased red cell indices and a shorter lifespan of RBCs during anemia. Specifically, red cell indices were decreased in cases with elevated MDA levels (10). This oxidative stress results from reactive oxygen species that harm the RBC membrane, contributing to a reduced lifespan of red blood cells during anemia. The impaired membrane integrity further exacerbates anemia-related complications (11). Thus, a vicious cycle occurs where anemia leads to oxidative stress, which in turn worsens anemia, ultimately resulting in adverse obstetric outcomes. Our study presents a contrasting viewpoint to findings by Zhao et al., which suggested that ferritin can amplify oxidative phenomena (12). In our study, serum ferritin exhibited a negative correlation with MDA, suggesting a different interaction in our population.

Anemia during pregnancy is associated with significant adverse obstetric outcomes for both mothers and infants. Research consistently highlights the increased risks linked to maternal anemia, including severe complications and poor neonatal outcomes (13) . The necessity for therapeutic administration of iron, as well as prophylaxis to all pregnant women in the initial stages of pregnancy and during the preconception period, may mitigate the oxidative damage caused by IDA during pregnancy, thus improving pregnancy outcomes. Studies involving larger populations

of pregnant women with IDA and their obstetric outcomes, in conjunction with iron supplementation, should be conducted to confirm the role of iron in preventing undesired outcomes during pregnancy.

Conclusion

This study highlights the significant relationship between iron deficiency anemia and oxidative stress in pregnant women, revealing increased MDA levels and decreased ferritin and hemoglobin levels. These findings indicate that oxidative stress plays a crucial role in the complications associated with IDA, affecting both maternal health and fetal development. Given the strong correlations between oxidative stress and adverse outcomes, it is imperative to prioritize early screening and iron supplementation for pregnant women to improve health outcomes. By addressing iron deficiency proactively, healthcare providers can mitigate the risks associated with anemia, ultimately promoting healthier pregnancies and reducing complications for both mothers and infants. Further investigation into the efficacy of iron supplementation in larger populations is warranted to solidify these findings and inform clinical practices.

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