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Iron Deficiency Anemia in Pregnancy: A review

Ghufran Mohammed Sadee Merie, Hadeel Tahseen Al-hashimi

Medical Technical Institute, Northern Technical University, Mosul, Iraq.

Email: mti.lec11.Ghufran@ntu.edu.iq, mti.lec180.hadeel@ntu.edu.iq

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ABSTRACT

The most prevalent nutritional condition affecting pregnant women globally is iron deficiency anemia (IDA). Reduced hemoglobin production and poor oxygen delivery to maternal and foetal tissues result from iron stores that are not enough to meet the increased physiological demands of pregnancy. Preterm delivery, low birth weight, maternal exhaustion, and postpartum depression are all linked to IDA during pregnancy. Improving maternal and neonatal outcomes requires early diagnosis through routine screening and prompt intervention with iron supplementation. The causes, clinical signs, diagnostic methods, and treatment options for iron deficiency anemia in pregnancy are examined in this review.

Keywords: Iron deficiency anemia, Pregnancy, Maternal health, Fetal development.

1. Introduction

Iron deficiency anemia (IDA) is a significant public health issue in the world today. Globally, pregnant women are at the highest risk for IDA. Adequate iron levels are essential in ensuring a healthy pregnancy, as it is vital for oxygen transport, energy metabolism, and cellular responses. During pregnancy, there is a dramatic rise in iron demand to meet the metabolic needs of the mother and developing fetus. Compensatory mechanisms, including enhanced intestinal iron absorption and mobilization of iron stores, are activated as a response to increased demand for iron. However, when these compensatory mechanisms fail to meet the demand in the context of inadequate iron intake, iron deficiency develops [1-4].

Despite being a preventable and treatable disease, IDA is the most common type of anemia globally. The incidence of IDA among pregnant women has rapidly increased in the past decade, especially in low- and middle-income countries. IDA in pregnancy is associated with various adverse maternal and fetal consequences. Given the devastating effects of IDA, early recognition and appropriate management of the condition are necessary [5]. There is currently a limited understanding of the dynamic changes in iron metabolism during normal and pathological pregnancies. To highlight the clinical problem of IDA in pregnancy, the current knowledge regarding the physiology of iron metabolism during pregnancy is first reviewed. Then, the recent advancements in understanding the pathophysiology of maternal IDA and its fetal consequences are summarized, and the current strategies used for the treatment of maternal IDA are also discussed [6, 7, 3]

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1.1. Definition and Prevalence

Anemia in pregnancy is defined as a hemoglobin concentration below 11 g/dL. The prevalence of anemia in pregnancy varies between 15% and 67% worldwide, with 30-65% in sub-Saharan countries and 15-25% in developed countries. Anemia is classified as mild, moderate, and severe, according to hemoglobin concentration. A variety of factors may contribute to anemia's onset, including poor diet, lack of iron-rich foods, emerging diseases, or an inability to absorb iron from food due to other health issues. Anemia in pregnant women has severe consequences on health, social, and economic development. It can increase maternal mortality, preterm labor, low birth weight infants, and postpartum depression [8]. Consequently, as maternal anemia can have severe complications for both mothers and children, the need for awareness and screening has been emphasized, especially for high-risk groups [9-11].

In pregnancy, the most common type of anemia is iron deficiency anemia (IDA). Iron is vital for hemoglobin production and other metabolic functions. Up to 40% of women of childbearing age are estimated to be anemic, most often due to iron deficiency. Inadequate intake or absorption of iron in conjunction with blood loss from menstruation may contribute to anemia outside of pregnancy. Nonetheless, food scarcity and other stressors may increase childbearing women's vulnerability to anemia. Data from 113 developing countries indicate that the prevalence of anemia in non-pregnant populations is 12.7%, while the rate jumps to 39% during pregnancy. Epidemiology studies across Asia, Africa, and Latin America have found a similarly high rate of anemia [12]. The maternal need for iron doubles in pregnancy due to an increased blood volume, development of the placenta, and development of the fetus, while iron stores are often low at conception, creating a delicate deficit [13, 1].

2. Physiology of Iron in Pregnancy

Preconceptually and during pregnancy, there is a rapidly rising need for iron to account for the expansion of maternal blood volume and to accrete red blood cells (RBCs) and iron in the developing fetus. A normal pregnancy consumes 500–800 mg of iron from the mother, or about 3 mg/day, with most of the demand being in the third trimester. Failure to meet iron requirements is common, leading to iron deficiency (ID) and iron deficiency anemia (IDA). While pregnancy is associated with a 'physiologic' anemia largely related to maternal volume expansion, it is paradoxically associated with an increase in erythrocyte production [1]. ID is a limiting factor for erythrocyte mass expansion and can contribute to a number of adverse pregnancy outcomes [14, 15].

As pregnancy progresses, a woman's body undergoes a series of physiological changes to accommodate the growing needs of both the mother and the developing fetus. This includes changes concerning iron metabolism. The mother's body must maintain a balance of iron absorption, storage, and transport throughout pregnancy. Adequate iron concentration in utero is essential for fetal growth and development, for example, to ensure sufficient hemoglobin synthesis [16]. The fetus relies on the mother for an iron supply. Thus, ID in the mother may cause a developmental compromise in the fetus, which may lead to adverse neurocognitive effects later in life. In addition, the developing placenta may also be affected by maternal ID, leading to pre-term birth or low birth weight in the offspring [17- 19].

2.1. Iron Requirements in Pregnancy

Normal physiology during a healthy pregnancy is associated with an increase in blood volume, red blood cell mass, and plasma expansion. The net effect results in a decline in hemoglobin concentration that is physiologic, and at term, a woman may have 500–600 mL more plasma and 200–300 mL more red blood cells. This cumulative volume expansion produces a decline in baseline hemoglobin concentration from approximately 12.0

g/dL preconception to 10.6 g/dL at 28 weeks and further to 10.2 g/dL at term. A normal pregnancy consumes 500–800 mg of iron from the mother. About 300 mg of iron transfers to the fetus and placenta, and 200–300 mg of iron is needed for increased erythropoiesis and expansion of maternal red blood cell mass. The remaining iron is used in various metabolic and cytologic functions. There is an increase in the requirement from 1.9 mg/day in the non-pregnant state to 5.2 mg/day in the 3rd trimester of pregnancy [1, 14, 15].

As the zeta-globin chain production decreases and the beta-globin chain production increases following the 1st trimester, the fetal liver begins to produce erythropoietin (EPO) in response to relative hypoxia in growth-restricted fetuses at approximately 9 weeks of gestation. This is an important developmental adaptation because, otherwise, the fetus would experience hypoxia from growth restriction because of the normal transplacental oxygen gradient. Erythropoietin from the maternal kidney stimulates expansion of erythrocyte production and erythrocyte mass/kg, which is greater than expansion of plasma volume and expansion of relative erythrocyte deficiency states. However, iron deficiency is a limiting factor for this expansion. Normal pregnancy is associated with a physiologic anemia largely related to maternal volume expansion. However, it is paradoxically associated with an increase in erythrocyte production and erythrocyte mass/kg. Anemia with a hemoglobin concentration no lower than 10 g/dL at term occurs in nearly all pregnancies and reflects a physiologic process rather than a deficiency state or underlying hematologic disorder [1,2, 20].

3. Causes and Risk Factors

Iron deficiency is the most common nutritional deficiency in the world. It is further aggravated by pregnancy, since physiological demands for iron increase greatly, especially in the later stages of pregnancy. As such, pregnant women are specifically at risk of developing iron deficiency, which can then lead to iron deficiency anemia. Anemia in pregnancy is harmful to both the mother and the fetus. Poorer maternal outcomes include increased risk of pre-eclampsia, vagal atonia, perineal laceration, postpartum hemorrhage, infected episiotomy, stillbirth, and mortality. Poorer fetal outcomes include low birth weight, intrauterine growth restriction, preterm birth, and perinatal death [5]. The increased risk of adverse outcomes implies the need for greater awareness and prevention efforts against iron deficiency anemia during pregnancy [21, 1, 22].

To plan for effective prevention and management, it is essential to first understand the causes and risk factors of iron deficiency anemia. During pregnancy, the demand for iron increases greatly. In a non-pregnant woman, approximately 0.9 mg of iron is needed to maintain iron balance, where iron loss through menstruation needs to be offset by iron intake through diet. In comparison, a pregnant woman needs to offset an estimated total iron loss of approximately 2.4 mg per day. This estimate can go higher, up to 5.5 mg per day, in cases of excessive iron loss due to gastrointestinal bleeding or menstrual abnormalities. Coupled with an inadequate dietary intake of iron, these conditions can lead to iron deficiency [23, 24].

In Indonesia, a number of groups are at higher risk of having iron deficiency anemia, including adolescents, pregnant women, vegetarians, those undergoing multiple pregnancies, and/or those with heavy menstrual bleeding. Adolescents may not have sufficient iron intake due to their transition to a new lifestyle where less attention is paid to their diet. A demand for iron greater than what can be supplied through diet is especially the case in pregnant women, since the requirement for iron increases greatly during pregnancy. On the other hand, iron from the diet might not be sufficient in vegetarians, since the most abundant source of dietary iron is red meat. Multiple or close pregnancies mean that the nutrients in the previous pregnancy are still being utilized by the body, making it more difficult to prepare for the subsequent pregnancy [14,22, 27]

3.1. Dietary Factors

Before conception and during the first trimester, it is advisable that every woman consume 30 mg of iron (Fe)/day. Iron supplementation has proven to be the most effective intervention in reducing maternal anemia; however, compliance is often low in developing countries. Hence, dietary choices are crucial. The bioavailability of iron depends on the dietary source: heme iron from meat is better absorbed than non-heme iron from plants. Hence, vegetarians and women with a low-meat diet often run into iron deficiency [5]. Pregnancy increases the need for iron, and many pregnant women worldwide have insufficient iron intake, especially young pregnant women. Goals for iron intake were not met by 65% of the pregnancies. Low meat consumption and no fortified food were the strongest contributors to dietary iron deficiency. Cultural restrictions on meat and fortified food were strongly linked to iron deficiency. Awareness concerning food interactions affecting iron absorption was very low, but extremely important information for pregnant women. Special attention concerning nutrition should be given to high-risk populations such as young pregnant women. It is vital to raise awareness about the critical role of diet in iron level problems during pregnancy and to recommend strategies for incorporating iron-rich foods into daily meals [26, 27].

Since iron (Fe) is essential for many bodily functions, iron deficiency (ID) can have serious health implications. The most severe consequence of ID is iron deficiency anemia (IDA), which occurs when the amount of red blood cells becomes too low. IDA is one of the most common nutritional disorders in the world. It is especially common among pregnant women because the need for iron increases dramatically during pregnancy [1]. Hence, it is crucial to assess the awareness and practices in preventing maternal IDA among pregnant women. Of the many micronutrients that are needed by pregnant women, iron is the most important because it is needed for the formation of hemoglobin. Hemoglobin plays a role in the transport of oxygen in the blood. Iron deficiency can cause a decrease in hemoglobin levels, resulting in anemia. Anemia is one of the problems that often occurs in pregnant women. Anemia in pregnant women can cause various complications to both the mother and the fetus. Since the consequences of IDA can be severe, it is thus important to investigate prevention practices and awareness concerning maternal IDA among pregnant women [2, 27, 28].

4. Clinical Presentation

Most of the clinical signs and symptoms of iron deficiency anemia resemble those of anemia in general. Fatigue is often the most obvious problem, noting that pregnancy is exhausting and fatigue is normal during pregnancy. Because of this, signs and symptoms may be overlooked or misattributed. It may be worth contemplating the psychosocial impact of fatigue and a reduced physical capacity to carry out other daily activities [1]. Therefore, it is important to have a thorough assessment of the level of fatigue and how this is impacting daily activities. Commonly observed signs and symptoms include pallor, shortness of breath, fatigue, and palpitations. However, it is noted that some pregnant women present with none of these signs despite having severely low hemoglobin levels [29]. Indeed, some women with the same laboratory values presented very differently; one was clearly unwell, and the other felt fine. This was likely because of the variance in how symptoms manifest based on the severity of anemia. A pregnant woman may present with a hemoglobin level of 100g/L yet feel fine in comparison to a woman with a 90g/L level who is fatigued, breathless, and has tachycardia. It appeared that as a woman's hemoglobin fell, she may become breathless and fatigued, but this was overly reliant on her presenting history. A thorough clinical assessment is vital as the physical findings of anemia may be subtle or missed altogether. A low hemoglobin may be flagged as abnormal on a blood test, but this does not automatically indicate that a woman is clinically anemic. Potentially severe iron deficiency with low hemoglobin levels may be missed in women who have large volumes of blood taken without baseline levels, as this makes it impossible to consider whether a low level is normal for that individual. Regardless of this, a poor clinical recognition of iron deficiency anemia highlights the need for at-risk women to attend follow-up assessments [30-32].

4.1. Signs and Symptoms

The signs and symptoms of iron deficiency anemia in pregnancy (IDAP) can differ widely from person to person. They can start quite mild, but if the anemia gets more severe, it can affect everyday life and the overall quality of life while pregnant. Common signs and symptoms of IDAP include fatigue, weakness, dizziness, lightheadedness, restless legs syndrome, brittle nails, pica, cold hands and feet, shortness of breath, and pallor [1]. During a physical examination, a health care provider might notice palpitation of the heart, high blood pressure, a heart murmur, or an enlarged heart as additional signs of IDAP. Recognizing the signs and symptoms of IDAP early on is crucial to prevention, as untreated moderate to severe anemia can lead to complications. In an effort to improve understanding of the condition and its impact during pregnancy, the physiological basis behind the most widely recognized symptoms is detailed, as well as the choices some women may make in regard to their behavior when symptoms become more severe. A description of the clinical picture presented by this condition follows, including the most common symptoms, as well as some that are less widely known but still potentially impactful [33- 35].

Fatigue is a common symptom in general during pregnancy, but with IDAP, it is more pronounced. A doctor's note may help, but even with the extra time off, fatigue can be overwhelming. Fatigue due to IDAP feels different than fatigue due simply to pregnancy. It is possible to sleep many hours and still feel fatigued or completely drained. Tasks that normally would not take much time or effort may take much longer due to exhaustion. Even more challenging is the feeling of not having enough energy to engage with a toddler, continue to make healthy meals, or keep up with household chores. There is a constant feeling that there is not enough time in the day to get everything done. This frustration only compounds feelings of inadequacy and failure [36, 37].

5. Complications

In pregnancy, iron deficiency anemia is associated with an increased risk for a myriad of maternal complications, many of which are very serious. For example, there is a two-fold increased incidence of preterm birth, a three-fold increase in low birth weight, and a four-fold increase in small-for-gestational-age infants [38]. Impaired neurodevelopment and anemia in neonates have also been reported as outcomes of iron deficiency anemia with pregnancy. On a similar note, it could be said that the effects of anemia on recovery during the postpartum period and on lactation are serious concerns as well. The risk of these conditions occurring directly correlates to the severity of the anemia. In addition, iron deficiency in pregnancy poses long-term threats to the child's health and development. For example, there is an increased risk for neonatal and childhood brain growth and developmental abnormalities. Thus, it would appear that there is a wide array of possible outcomes as a result of either poorly managed anemia or anemia that is left untreated altogether. Because of the possibility of such outcomes, preventative strategies would be necessary, and those who are already anemic should be monitored carefully throughout their pregnancy [1,13, 27].

For the mother, iron deficiency anemia in pregnancy worries about the more obvious outcomes of this condition, including preterm labor, low birth weight, and other complications. These complications are critical issues in pregnancy. However, it could be said that there are also larger issues at hand beyond just these more obvious complications. Anemia during pregnancy could impact the mother's ability to recover postpartum and could impact lactation as well. Despite this condition's prevalence, these issues do not appear to be widely considered. And for the child, anemic conditions during pregnancy could lead to neurodevelopmental complications or leave the child anemic after birth. Hence, a similar situation arises here as well, where a wider breadth of possible outcomes might need to be considered beyond just the more obvious concerns [39- 41].

5.1. Maternal Complications

Iron deficiency anemia (IDA) during pregnancy can cause a myriad of complications for the maternal side. Even mild cases of anemia can make an expectant mother face increased fatigue, weakening the physical capability to perform daily life tasks that require higher energy, such as house chores or caring for older children. These effects may lower maternal well-being [38]. Moderately anemic mothers may also struggle to meet the minimal physical capabilities demanded by driving or attending regular check-ups, further isolating them from assistance in intervention efforts. These physical restrictions become more pronounced in tandem with caring for and being present for a newborn. Therefore, it is crucial to diagnose and intervene in the condition as soon as possible, ideally during early pregnancy when there are no other stress factors applied to the infant, and anemia treatment would not be complicated by time constraints for the medical personnel [42-44].

In more severe cases, additional risks arise for the mother, most notably the complications regarding birth. Maternal anemia is a significant risk factor for post-partum hemorrhage, as it is difficult for the uterus to contract and induce hemostasis after the placenta is detached under inadequate iron levels. Risks of infection also increase, as the immune response cannot operate effectively under low iron levels. Such burdens would directly impose additional stresses on the healthcare resource, rendering the potential dangers of untreated maternal anemias not just a maternal concern but also societal ones [45]. Furthermore, it is imperative to closely monitor compensatory physiologic adaptations to low iron, as they may bring about other systemic complications if taken too far or improperly handled. For instance, cardiac function would be affected as heart rates surge from low iron levels, an efficiency loss amplifying a potential left ventricle failure. Hydrochloric acid secretion in the stomach may also be inadequately conducted under low iron levels. Therefore, it is crucial that the healthcare provider be cognizant of the symptoms such conditions bring and act on them expediently, such as prescribing proton-pump inhibitors in conjunction with iron supplements to prevent serious outcomes [46- 48].

6. Management

The objectives of management are to alleviate the symptoms and sequelae of IDA, correct iron deficiency, restore normal erythropoiesis, and replenish iron stores. This can be done through non-pharmacological and/or pharmacological means. Dietary modifications should be the foundation of treatment. Pregnant women should be encouraged to increase their iron intake through diet. Foods high in iron are meat (especially red meat and animal organs), some fish and shellfish, dark-green leafy vegetables, whole grains and enriched bread and cereal, beans, and dried fruit. Only 1–2 hours after eating, vitamin C-rich foods should be consumed because they enhance the absorption of iron from plant sources. Calcium-rich foods, dairy products, and tea should be avoided as they inhibit iron absorption [29]. Oral iron is the most commonly used medication during pregnancy. Because of low compliance in daily dosage regimens, iron supplementation should be given as much as possible in a single dose schedule. In the case of IDA, a single dose of 100–200 mg of elemental iron, which contains 200–400 mg of iron salt, should be given. If the patient can tolerate the therapy well and adherence is ensured, this dosage can be maintained for 6 weeks after hemoglobin normalizes. This is to replenish iron stores, and serum ferritin should be checked after that period [38]. If the patient has an allergy or intolerance to parenteral agents, iron supplements that contain encapsulated iron should be considered. With encapsulation, i.e., using polysaccharide iron(III) complex, iron is tightly encapsulated in a polymer matrix. This creates a steric hindrance that prevents iron from leaking out into the pH of the upper gastrointestinal tract, where most of the iron is dissolved and absorbed, hence reducing side effects during pregnancy. If there is insufficient clinical and laboratory improvement after 3 weeks or if the patient has ferrous iron intolerance, iron salts with a different ion oxidation state (i.e., iron polymaltose complex) should be tried instead. If this fails, intravenous treatment must be initiated. If there is a clinical suspicion of ongoing bleeding or if the patient is hemodynamically unstable, intravenous iron therapy should be given before any further investigation. With severe IDA, intravenous iron is indicated if the hemoglobin level is < 70 g/L. Although there is only limited experience with fetal safety of various intravenous preparations, iron preparations with the highest molecular weight of dextran (5000 Da) should generally be avoided. Low-molecular-weight dextran (350 Da) has been associated with life-threatening maternal allergic reactions. Ferric carboxymaltose and iron isomaltoside have been studied in well-controlled clinical trials in pregnancy and postpartum and therefore should be preferred with safety concerns. With ferrous hydroxide and fucoidan complex, it is also possible for IDA patients who have an intolerance to parenteral iron agents. Safety regarding maternal allergic reactions is because fucoidan stabilizes iron nanoparticles, keeping them in an ionic state that is non-absorptive at pH 4.0. Treatment effectiveness should be monitored by checking hemoglobin and hematocrit 1 week after treatment initiation; if these values increase > 10 g/L, the regimen should be continued. If there is no increase in hemoglobin, adherence should be ascertained, and if the patient has complied with the regimen for at least 3 weeks, consider changing the treatment strategy. If oral iron is switched to parenteral treatment, laboratory tests should be done to rule out other causes of anemia. Counseling on the importance of adherence and how to take the drug should be done at the start of treatment. Other than side effects, the most common reason for non-adherence is the wrong assumption that oral iron is superfluous because hemoglobin is normal. Iron supplementation must be continued at least until delivery as IDA during pregnancy is associated with poor fetal outcome and preterm delivery [49- 51].

6.1. Iron Supplementation

This section seeks to address the role of iron supplementation in the management of anemia during pregnancy. The types of iron you're able to supplement with, their efficacy, side effects, and recommended dosages according to varying levels of deficiency will be discussed. As it's widely known that compliance with medication regimens is a common issue across the board, quick thoughts on timing and adherence to supplementation regimens will be mentioned to ensure maximum benefit is gained from iron supplementation. Additionally, potential interactions with other medications and food will be reviewed, along with some suggestions on how to best counsel patients on managing side effects, which will be useful in the practice of medicine, and of course, continued education on the topic as possible side effects and lack of efficacy can be a significant point of concern for patients [50, 52, 53].

Iron deficiency is the most common nutritional disorder prevalent in pregnant women and is a leading contributor to the global burden of disease. The physiological, social, and developmental factors that enhance the feasibility and risk of iron deficiency during pregnancy will be briefly addressed. Moreover, the most common strategy for management, which involves the initiation of oral iron supplementation during pregnancy, will turn to focus on the importance of regularity and adherence to the supplementation plan, the possible side effects that patients may face, and how best to counsel them on minimizing these effects. It should be noted that the aim is not to give a comprehensive overview of iron deficiency anemia, but rather to provide assistance in effective supplementation practices post-diagnosis. As each patient's needs will differ, it is essential to determine the most appropriate form and plan for each patient individually [4, 27, 54].

7. Prevention

Communication is critically important in promoting awareness among pregnant women regarding dietary iron needs, the symptoms of anemia, and the sources of iron [5]. Pre-pregnancy counseling, including nutritional assessment and recommendations, is essential in preventing a variety of health issues, including anemia, and should be a routine aspect of care in clinical settings. Screening for anemia, by assessing risk factors or through hemoglobin measurement, should occur at every prenatal visit to ensure early detection, particularly for women at high risk. Outreach programs should target communities that lack access to healthcare to educate low-income populations, immigrants, and women with limited education about the importance of nutrition during pregnancy. Community health initiatives can promote dietary practices that improve iron intake among vulnerable populations. Education regarding food choices that enhance or inhibit iron absorption is equally important [55]. Food fortification programs should focus on widely consumed staples such as flour or salt in order to increase iron levels in the entire population, including pregnant women [1, 56, 57].

In developing countries, free iron supplementation should be made available to women at the first prenatal visit, with community health workers ensuring compliance among those unable to attend clinics. Policies should mandate that health facilities build partnerships with local organizations to promote adherence to iron supplementation programs. Primary health facilities should be encouraged to collaborate with community leaders in creating supportive environments for maternal nutrition. For every health facility, a community support group should be instituted to include women's groups, local leaders or religious authorities, and members of other sectors such as agriculture or education. This group should meet regularly to assess barriers to improved maternal nutrition and develop feasible solutions [58, 59].

7.1. Importance of Prenatal Care

Prevention strategies must be developed and effectively implemented to decrease the incidence of iron deficiency anemia in pregnant women. The most important preventative approach is to ensure that all women at risk for iron deficiency anemia receive adequate and appropriate prenatal care. Adequate prenatal care consists of ongoing care throughout pregnancy, including regular check-ups to monitor the mother's general health as well as nutritional health. During each visit, health professionals should be able to assess risk factors for iron deficiency anemia and develop an individualized care plan to address these concerns. Along with monitoring, it is also key for health care providers to educate women on their need for iron during pregnancy and what dietary sources can provide this nutrient [5]. Unfortunately, some populations face barriers to accessing prenatal care, whether it be a lack of transportation, financial constraints, or language barriers. These issues must be recognized and addressed to ensure all women are receiving the care they need. Prenatal education sessions can also be an effective method to improve adherence to recommended nutritional practices and supplementation [38]. As part of a comprehensive prenatal education program, women could receive information on the importance of iron during pregnancy, food sources of iron, the difference in absorption rates between heme and non-heme iron, and the importance of taking vitamin C with non-heme iron sources. Efforts should also be made to involve partner support in dietary changes, as it has been shown that those who perceive their partners as being supportive of dietary changes are more likely to adhere to them. By addressing these concerns, the hope is to significantly decrease the incidence of iron deficiency anemia in pregnant women. Prenatal care is important not only for the health of the baby but the health of the mother. Continuous care throughout pregnancy should be emphasized [60- 62].

8. Future Directions in Research

New horizons for research on iron-deficiency anemia during pregnancy are being explored. There is an imperative need for studies that will assess the long-term outcomes for both mothers and infants who experience some form of anemia during pregnancy. How do these effects manifest, and for what duration? Future inquiries may include innovative diagnostics that are rapid, new materials that are cost-effective, and/or minimally invasive approaches, such as saliva sampling. This would supplement the development of more effective treatments for identified iron-deficiency anemias. This subject could further emphasize the necessity of interdisciplinary research involving nutrition, obstetrics, and public health. For instance, it is crucial to understand how current insights into genetics affect susceptibility to inadequate iron intake. Investigating why certain pregnant women are at risk of developing anomalies in iron parameters despite an ostensibly adequate diet is essential. This calls for the exploration of the relevance of new iron formulations or other interventions, particularly their significant impact on patient adherence to treatment. Such inquiries may necessitate collaborations involving researchers from the pharmaceutical industry, obstetricians, and public health scholars, aimed at better anticipating the critical importance of long-term treatment adherence. Ultimately, this may prompt a reconsideration of the safety implications of ferritin levels exceeding iron requirements, as prior nutritional studies have indicated that excessive ferritin is undesirable in mammals. This suggests an avenue for research to examine the impact of iron states on the development of neurological disorders [63- 65].

8.1. Novel Therapies

Recent calls have highlighted the need for new considerations in iron deficiency anemia (IDA) management efforts in pregnant women. Although the payload of several ongoing clinical trials will determine the feasibility and safety of exciting new options, a promising future is within reach. New supplementary alternatives, focusing on either oral formulations or intravenous delivery, are in advanced clinical assessment stages. Other innovative approaches focus on breakthroughs in the understanding of pharmacokinetics, stability, and bioavailability of iron treatments. However, there is a need to improve new patient-centered approaches in the development of these therapies. Dietary and complementary therapies may counteract traditional time windows of supplementation regarding daily regimen iron treatment. Nonetheless, concerns arise with potential chemotherapeutic inhibition of good absorption, as several anemic women are candidates for anti-cancer treatment. Accessibility is also an issue, as anemia and poor pregnancy outcomes are often observed in women from diverse populations, for whom novel treatments may not yet be readily available [66, 67].

With a delivery slam dunk in both allopathic and alternative therapy arms, there is immense excitement regarding other options on the horizon for treating IDA in pregnancy. Novel oral formulations, some recently in advanced clinical assessment stages, promise exciting times ahead for managing IDA. Currently in ongoing clinical trials, free iron has been liberated from confinement in a drug carrier, enabling rapid absorption. Two alternative formulations co-precipitate iron with hydroxylated putrescine or glycine, and both modify iron's transit through the gastrointestinal tract. Evaluation suggests iron bioavailability from a novel ferric isopropylamine phytate formulation is equal to that of another common iron supplement. Post-gastric iron delivery might elicit fewer side effects thanks to localizing an enteric coating to the small intestine. Iron-loaded carboxymethyl resistant starch nanoparticles could also liberate iron rapidly and have been shown to increase hemoglobin levels significantly in specific animal models. Alongside new supplementary alternatives, exciting new therapeutic avenues focused on intravenous delivery are in advanced clinical assessment stages. Iron nanoparticles, stabilizing iron within a chitosan matrix, showed dose-dependent efficacy in iron-sufficient and iron-deficient models. A vasopressin oxytocin receptor antagonist significantly increased the uptake and transfer of intravenous iron in a pregnant model by expanding maternal circulation. Another experimental avenue focused on intravenously administered desferrioxamine transfer of iron across the blood-brain barrier to neonatal animals, although concerns arise regarding safety and withdrawal from treatment options [68- 70].

9. Conclusion:

With serious consequences for the health of the mother and the foetus, iron deficiency anaemia is still a major public health concern during pregnancy. Its complications can be significantly decreased by effective prevention and treatment, which includes iron supplementation, regular screening, and dietary counselling. Raising awareness among pregnant women and healthcare professionals is crucial to ensuring early detection and management, which will ultimately result in healthier pregnancies and improved birth outcomes.

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