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Review Article

Effects of High Haemoglobin Levels in Pregnancy and their Complications on Maternal and Foetal Outcomes

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ABSTRACT

High haemoglobin levels during pregnancy are increasingly recognized as a potential risk factor for adverse maternal and foetal outcomes. The development of the foetus and the overall results of the pregnancy are greatly influenced by the health of the mother throughout this crucial time. Although iron deficiency and anaemia are well-known issues, high maternal haemoglobin levels have gotten relatively less attention despite the problems they may pose. The many impacts of elevated haemoglobin levels during pregnancy are examined in this paper, along with the implications for the health of the mother and the foetus. Elevated haemoglobin is linked to increased maternal hepcidin levels, disrupting iron transfer to the foetus and potentially leading to intrauterine growth restriction and foetal hypoxia. High maternal haemoglobin levels have been connected to negative outcomes such preeclampsia, gestational diabetes, hypertension, and postpartum problems, yet they are sometimes misunderstood as signs of excellent health. The main cause of these dangers is the inability of plasma volume expansion to occur, which results in higher blood viscosity. High levels of haemoglobin can also hinder the exchange of nutrients between the mother and the foetus, limiting the growth of the foetus and raising the risk of low birth weight, preterm birth, small-for-gestational-age babies, and even stillbirth. Iron homeostasis is further upset by elevated hepcidin levels linked to high haemoglobin, which may result in iron shortage in the foetus. In light of these results, it is crucial to closely monitor haemoglobin levels during pregnancy in order to maximize outcomes for both the mother and the foetus. Future studies should concentrate on identifying at-risk groups to reduce problems, highlighting the need of balanced maternal nutrition, and improving clinical guidelines for haemoglobin management.

Key words: Haemoglobin, Preeclampsia, Hepcidin, Hypertension.

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INTRODUCTION

Pregnant women should avoid any risk factors that could impact both their health and the growth and development of their unborn child, since pregnancy is a delicate time in their lives. Iron deficiency and associated anaemia, which is a risk factor for preterm delivery, prematurity, and small for gestational age, birth, and weight, are among the serious issues that pregnant women may encounter.[1] Apart from anaemia, a number of studies have discovered a link between high maternal haemoglobin and unfavourable delivery outcomes, such as Small-for-Gestational-Age (SGA), Preterm Birth (PTB), and Low Birth Weight (LBW). However, its impact on pregnancy outcome has not gotten as much attention as anaemia since a high maternal haemoglobin level is commonly misinterpreted as having good iron status.[2] Elevated maternal Hb levels have not gotten enough attention and are typically thought to be an indicator of good nutritional status when compared to anaemia. Elevated haemoglobin levels have been linked in recent decades to a number of negative outcomes for both mothers and infants, including foetal mortality, PTB, LBW, SGA, and Gestational Diabetes Mellitus (GDM).[3] The failure of the plasma volume to expand, which raises the viscosity of the mother's blood, is usually thought to be the cause of high Hb levels during pregnancy. The intervillous space is adversely affected by hyper viscosity, which results in inadequate maternal-foetal exchange. Foetal development abnormalities may result directly from this decrease in nutrition transport, or they may result indirectly.[4,5] Hypovolemia or haemoconcentration, which is typically caused by preeclampsia or pregnancy-induced hypertension, is the cause of greater haemoglobin concentrations during pregnancy, according to a number of other research. Polycythaemia vera is the only disorder with increased haemoglobin that results from the formation of faulty red blood cells and is not controlled by tissue oxygen drive, which can lead to adverse maternal

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outcomes, including hypertensive disorders and thromboembolic events. This review aims to explore the multifaceted effects of high haemoglobin levels during pregnancy, elucidating their implications for both maternal and foetal outcomes.[6-8] In fact, during pregnancy, one of the most important conditions affecting both poor maternal and foetal outcomes is anaemia. In contrast, maternal high haemoglobin levels have not received that much attention. Emerging evidence indicates high haemoglobin concentrations mostly resulting from inadequate plasma volume expansion with such risks as preeclampsia, gestational diabetes, preterm birth, low birth weight, and stillbirth. These may be influenced by poor uteroplacental perfusion and high maternal hepcidin, which restrict iron availability to the foetus. This article will review the clinical implications of high haemoglobin levels in pregnancy with special regard to maternal and foetal outcomes. Such a review would bring to the fore the need for careful monitoring as well as individualized intervention to optimize and ensure pregnancy care and reduce risks associated with it.

OVERVIEW OF HAEMOGLOBIN LEVELS IN PREGNANCY

Understanding haemoglobin levels during pregnancy is crucial, as they play a significant role in maternal and foetal health. Normal haemoglobin levels typically range from 12 to 16 g/dL for pregnant women; however, variations can occur due to factors such as nutritional status, pre-existing medical conditions, and the physiological changes accompanying pregnancy. Elevated haemoglobin levels can indicate polycythaemia, which may lead to adverse outcomes, including increased blood viscosity and related complications. Conversely, low haemoglobin levels, often resulting from anaemia, are associated with insufficient oxygen delivery to the foetus, impacting growth and development, ultimately linking maternal health directly to neonatal outcomes.[9] Moreover, innovations in treatment approaches, such as the use of bovine lactoferrin, have shown efficacy in addressing anaemia, enhancing iron absorption, and regulating hepcidin levels in pregnant women.[10] Therefore, attention to haemoglobin levels is essential for optimizing both maternal and foetal health during pregnancy.

EFFECTS OF HIGH HAEMOGLOBIN LEVELS ON MATERNAL HEALTH

High haemoglobin levels during pregnancy, while often perceived as a marker of maternal health, can lead to significant complications for both mother and foetus. Elevated haemoglobin is associated with various inflammatory states, including preeclampsia and obesity, which have been shown to increase maternal hepcidin levels. Hepcidin acts as a master regulator of iron bioavailability, and its higher concentrations can lead to reduced iron transfer to the foetus, thereby compromising foetal iron status and potentially impacting development.[11] A failure in plasma volume expansion during pregnancy may be indicated by a high haemoglobin level. Plasma volume typically expands by 50% during a typical pregnancy; if this expansion is not achieved, haemoconcentration or higher-than-expected haemoglobin levels follow. Preeclampsia and pregnancy-induced hypertension, disorders linked to inadequate foetal growth due to inadequate placental-foetal perfusion, are characterized by a lack of normal plasma volume expansion. Therefore, pregnancy-induced hypertension is the most likely explanation for the correlation between high haemoglobin levels and SGA.[2] High Hb levels have been linked to maternal hypertension, preeclampsia, and diabetes. They have also been anticipated to result in inefficient placental and foetal oxygen and nutrition supply, increase blood viscosity, and induce inadequate plasma volume expansion.[12] Furthermore, the relationship between high haemoglobin concentrations and preterm birth underscores the complexity of managing maternal health during pregnancy; infants born preterm are at elevated risk for mortality and long-term morbidities.[13] Thus, while high haemoglobin levels may correlate with certain physiological benefits, they can also indicate underlying pathologies that threaten both maternal and foetal health. Adverse maternal outcomes due to high haemoglobin levels has been illustrated in Table 1.[14]

RISKS ASSOCIATED WITH ELEVATED HAEMOGLOBIN LEVELS

Elevated haemoglobin levels during pregnancy present significant risks that can adversely affect both maternal and foetal outcomes. Research indicates that high maternal haemoglobin concentrations, particularly those above 140 g/L, can more than double the risk of stillbirth, highlighting a critical concern for expectant mothers with increased haemoglobin levels.[15] Furthermore, while multivitamin supplementation has been shown to reduce low birth weight and small-for-gestational-age births, evidence suggests that it has a negligible effect on overall haemoglobin levels during pregnancy.[16] Maternal mortality, pregnancy and postpartum depression, blood transfusions, postpartum haemorrhage, and preeclampsia were among the maternal adverse outcomes. Low birth weight (LBW; birth weight <2500 g), SGA (birth weight below the 10th percentile for gestational age), Preterm Birth (PTB; <37 weeks of gestation), stillbirth (e.g., foetal death, foetal death at or after 28 weeks gestation, birth of foetus at 22 gestational weeks, or later with no signs of life), perinatal mortality (defined as the sum of foetal deaths (28 weeks or more gestation) and infant deaths occurring less than 7 days after birth), neonatal mortality (death within the first 28 days of life), and infant mortality (death within the first year of life) were among the child health adverse outcomes.[17] Throughout pregnancy, there was a tendency to correlate stronger uteroplacental resistance with maternally raised haemoglobin levels. Foetal head circumference, length, and weight growth restriction from the 3rd trimester onward was linked to higher

maternal haemoglobin levels. Lower birth weight and a higher chance of unfavourable birth outcomes were linked to higher maternal haemoglobin levels.[18] This raises the question of whether preventative measures are sufficient in mitigating the risks associated with elevated haemoglobin. It is crucial to understand that not only does high haemoglobin correlate with increased stillbirth risk, but it also underscores the complexity of identifying underlying health issues that may contribute to these elevated levels, ultimately necessitating careful monitoring and management throughout pregnancy.

IMPLICATIONS OF HIGH HAEMOGLOBIN LEVELS ON FOETAL DEVELOPMENT

High haemoglobin levels during pregnancy can have significant implications for foetal development, particularly concerning iron bioavailability and potential complications. Elevated haemoglobin concentrations may lead to increased maternal hepcidin levels, which in turn could restrict the availability of iron to the foetus, ultimately affecting its growth and development. Notably, hepcidin is known to be lower during pregnancy to ensure iron transfer to the developing foetus; however, inflammatory conditions like preeclampsia can result in higher hepcidin levels, creating a paradox where iron availability is compromised despite elevated haemoglobin levels.[11] Furthermore, high haemoglobin can also be associated with Rh isoimmunization, which presents serious risks such as haemolytic disease of the newborn if left unaddressed.[19] Thus, maintaining optimal haemoglobin levels is crucial for ensuring both maternal health and favourable foetal outcomes. Adverse foetal outcomes due to high haemoglobin levels has been illustrated in Table 2.[14]

POTENTIAL COMPLICATIONS FOR FOETAL GROWTH AND HEALTH

Elevated haemoglobin levels during pregnancy can pose significant risks to foetal growth and health, complicating the delicate balance required for optimal development. High haemoglobin levels often correlate with increased hepcidin, the principal regulator of iron metabolism, which can impair iron bioavailability necessary for foetal growth.[11] Insufficient iron transfer can lead to foetal anaemia, ultimately restricting oxygen delivery and increasing the likelihood of developmental delays. Additionally, conditions associated with elevated haemoglobin, such as preeclampsia, may further compromise foetal well-being by contributing to placental insufficiency and an elevated risk of preterm birth.[13] Low birth weight is also a risk factor for abnormally high haemoglobin concentrations, which often suggest inadequate plasma volume expansion and perfusion. Foetal development limitation is linked to high maternal haemoglobin levels.[20] These complications underscore the importance of monitoring maternal haemoglobin levels throughout pregnancy to ensure that both the mothers and the foetus nutritional and health needs are adequately met. Ultimately, addressing these issues is critical to improving maternal and foetal outcomes and minimizing long-term health consequences for the child.

DISCUSSION

Despite growing evidence that links raised haemoglobin concentrations to negative outcomes for both the mother and the foetus, the focus on anaemia has long overshadowed high maternal haemoglobin levels during pregnancy.[2,21,22] The physiological, clinical, and public health effects of elevated maternal haemoglobin levels are examined in this conversation, with a focus on the necessity of close observation and control during pregnancy.

PHYSIOLOGICAL MECHANISMS AND PATHOPHYSIOLOGY

One of the major haematological changes that occurs during pregnancy is the growth of plasma volume, which is essential for maintaining healthy maternal-foetal circulation. Increased blood viscosity results from haemoconcentration, which happens when plasma volume does not sufficiently expand. By decreasing placental perfusion, this hyper viscosity might hinder the exchange of nutrients between the mother and the fetus, thus limiting the growth and development of the foetus.[23,24] Conditions like preeclampsia, pregnancy-induced hypertension, and gestational diabetes-all of which are connected to compromised placental function-have been related to elevated haemoglobin levels.[25,26] Furthermore, elevated haemoglobin levels could be an indication of underlying conditions such chronic hypoxia or polycythaemia vera, both of which can be extremely dangerous during pregnancy.[27] The connection between haemoglobin levels and pregnancy outcomes is further complicated by the regulating function of hepcidin in iron metabolism. Increased hepcidin levels frequently accompany elevated maternal haemoglobin, which may lower the foetus's iron bioavailability. Ironically, this raises the possibility of foetal iron shortage, which could cause developmental delays and long-term health issues. According

Table 1: High maternal haemoglobin and its adverse maternal outcomes.[14]

High maternal haemoglobin (>130 g/L)	Adverse maternal outcomes
Preconception	Gestational diabetes.
1st trimester	Gestational diabetes, Preeclampsia.
2nd trimester	Preeclampsia, Postpartum haemorrhage, Postpartum depression.
3rd trimester	Gestational diabetes, Preeclampsia, Postpartum haemorrhage, Postpartum depression.

Table 2: High maternal haemoglobin and its adverse foetal outcomes.[14]

High maternal haemoglobin (>130 g/L)	Adverse foetal outcomes
Preconception	Low birth weight, preterm birth, small for gestational age, still birth.
1st trimester	Very low birth weight, Low birth weight, preterm birth, small for gestational age, still birth, neonatal mortality.
2nd trimester	Low birth weight, small for gestational age, preterm birth, still birth, perinatal mortality.
3rd trimester	Low birth weight, small for gestational age, preterm birth, still birth.

to research, inflammatory conditions like obesity and metabolic diseases may exacerbate the issue by raising hepcidin levels.[11,28]

CLINICAL IMPLICATIONS AND PREGNANCY OUTCOMES

High maternal haemoglobin levels have clinical implications that goes beyond theoretical worries because numerous studies have shown links to unfavourable pregnancy outcomes. Pregnant women who have haemoglobin levels higher than 130 g/L are more likely to experience postpartum haemorrhage, preeclampsia, and hypertensive diseases. In extreme situations, haemoconcentration may increase maternal morbidity and death by putting women at risk for thromboembolic events.[14,29] From the foetal perspective, high maternal haemoglobin has been linked to Small-for-Gestational-Age (SGA) births, preterm delivery, Intrauterine Growth Restriction (IUGR), and even stillbirth. High haemoglobin levels have been linked to higher uteroplacental resistance, which compromises the foetus's ability to get oxygen and nutrients, according to studies. Given that foetal hypoxia can have long-term effects, such as cognitive and neurodevelopmental deficits, this is very worrying.[12,30] High amounts of haemoglobin during pregnancy are also associated with Rh isoimmunization, which, if left untreated, can cause haemolytic illness in the foetus. The significance of thorough prenatal screening and customized care regimens for mothers who are at risk is highlighted by this disorder.[19]

PUBLIC HEALTH CONSIDERATIONS AND PREVENTATIVE STRATEGIES

Public health activities should concentrate on raising awareness and enhancing clinical guidelines for haemoglobin monitoring in view of the mounting research that highlights the hazards associated with elevated maternal haemoglobin. The main goal of current prenatal care is to prevent anaemia, but a more comprehensive strategy that takes into account both haemoglobin spectrums is required. Maintaining healthy haemoglobin levels requires nutritional interventions. Overdosing on iron supplements can raise haemoglobin levels and should be carefully controlled, especially in women who are not iron deficient. Rather, dietary guidelines should be customized to meet the needs of each mother, guaranteeing the best possible iron intake while avoiding unnecessary haemoconcentration.[3,8,15,23]

FUTURE RESEARCH AND RECOMMENDATIONS

While current research highlights the dangers of high maternal haemoglobin, further studies are needed to refine clinical thresholds and management strategies.[31] Key areas for future investigation include:

The role of genetic and environmental factors in predisposing certain populations to elevated haemoglobin levels.

The impact of lifestyle interventions, including hydration strategies and controlled supplementation, in preventing haemoconcentration.

The potential for novel biomarkers to predict high haemoglobin-related pregnancy complications.[32]

In clinical practice, routine haemoglobin screening should be integrated into standard prenatal care protocols, with individualized interventions for women presenting with elevated levels. Early detection and targeted management strategies can help mitigate risks and improve overall pregnancy outcomes.

CLINICAL FINDINGS

Increased maternal haemoglobin during pregnancy has become a focal point for clinical research in the past few years, which had previously overshadowed by the study of anaemia. There appears to be a further relationship between high Hb levels, especially with concentrations more than 130 g/L, and many adverse maternal and foetal outcomes.

Maternal Findings

The pregnancy-associated hypertensive disorders including preeclampsia and pregnancy-induced hypertension are due to increased blood viscosity from insufficient plasma volume expansion affecting the mother because of high levels of Haemoglobin.[33-35] High Haemoglobin is also associated with higher cases of Gestational Diabetes Mellitus (GDM), postpartum bleeding, and postpartum depression.[36,37]

Foetal Findings

High maternal Hb increases the likelihood of Low Birth Weight (LBW), Small-for-Gestational-Age (SGA), Intrauterine Growth Restriction (IUGR), preterm birth, stillbirth, and neonatal mortality. Thus, high levels of Hb are seen to restrict uteroplacental perfusion, where less oxygen and nutrients are exchanged, which thus impairing foetal growth.[38-40]

The current status of normal haemoglobin levels in pregnancy in 1st and 3rd trimesters is 11 g/dL or more and then in 2nd trimester is 10.5 g/dL or more.[41] A limitation for this study was the unavailability of adjustments for confounding factors, which are known to affect haemoglobin levels, such as maternal, environmental, or sociodemographic risk factors, due to inconsistent information available. Such factors can significantly show adverse outcomes.

CONCLUSION

In concluding the review of high haemoglobin levels in pregnancy, it is crucial to recognize the implications these elevated levels have on both maternal and foetal outcomes. While some may perceive higher haemoglobin concentrations as beneficial, the associated risks-such as an increased likelihood of complications like preterm birth-must not be understated. A thorough assessment of relevant literature, including environmental factors contributing to such outcomes, reveals a concerning trend that necessitates preventive strategies targeted toward at-risk populations. For instance, the study highlights that environmental toxicants may play a significant role in preterm births, emphasizing the need to mitigate exposure to these hazardous elements. Additionally, research indicates a complex relationship between maternal haemoglobin levels, educational background, and birth weight, underscoring the multifaceted nature of anaemia and its prevalence among pregnant women. Given these risks, medical professionals need to concentrate on maintaining balanced haemoglobin levels throughout pregnancy rather than just preventing anaemia. Prenatal care, tailored nutritional therapies, and routine monitoring are essential for reducing the negative consequences of elevated haemoglobin levels. In order to maximize the health of both the mother and the fetus, future research should focus on improving clinical guidelines and investigating practical methods for controlling haemoglobin levels. Reducing pregnancy-related problems and improving overall perinatal outcomes are two benefits of addressing this issue holistically. Ultimately, ongoing research and public health initiatives are essential to address these critical challenges effectively.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

SGA: Small-for-Gestational-Age; **PTB:** Preterm Birth; **LBW:** Low Birth Weight; **GDM:** Gestational Diabetes Mellitus; **IUGR:** Intrauterine Growth Restriction.

SUMMARY

This review highlights a less-recognized but major influence of elevated maternal haemoglobin levels on both maternal and foetal outcomes during pregnancy. Since the time of the ancients, anaemia has been a central concern in prenatal care. However, elevated haemoglobin levels are usually misconstrued as being indicative of good maternal health, indicating the setting of poor plasma volume expansion. This causes increased blood viscosity and increased maternal hepcidin levels, leading to impaired transfer of iron to the foetus and decreased placental perfusion. Elevated maternal haemoglobin is linked with adverse maternal outcomes that include Preeclampsia, Gestational diabetes mellitus, Hypertension, Postpartum haemorrhage, and depression. The foetal complications reportedly associated with high maternal haemoglobin include Low Birth Weight (LBW), Small-for-Gestational-Age (SGA), Preterm Birth (PTB), Intrauterine Growth Restriction (IUGR), Stillbirth, Neonatal and infant mortality. The review emphasizes iron supplementation should be given at balanced doses, with individualization of prenatal care and ongoing monitoring of haemoglobin status throughout pregnancy. Future research is called for to refine clinical thresholds and examine genetic, environmental, and nutritional factors for elevated haemoglobin levels in pregnancy.

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