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IMPACT OF MATERNAL ANEMIA ON PLACENTAL MORPHOLOGY AND STRUCTURE: COMPENSATORY MECHANISMS AND IMPLICATIONS FOR FETAL HEALTH OUTCOMES

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ABSTRACT

Maternal anemia is a common condition during pregnancy, with potential implications for both maternal and fetal health. This study investigates the impact of maternal anemia on placental morphology and structure, focusing on key parameters such as placental weight, volume, diameter, thickness, and the number of cotyledons. A total of 150 placentae were examined, comprising 120 from anemic pregnancies and 30 from normal pregnancies. The findings reveal significant differences between the two groups, with increased placental weight, volume, and diameter observed in anemic pregnancies. These alterations suggest compensatory mechanisms such as placental hypertrophy aimed at mitigating the effects of reduced oxygen supply to the fetus. However, a reduction in the number of cotyledons was noted in anemic pregnancies, which may impair placental function. These morphological changes underscore the placenta's adaptive responses to maternal anemia, but also highlight the potential risks of complications such as intrauterine growth restriction, low birth weight, and preterm birth. The study emphasizes the importance of early detection and management of anemia during pregnancy to optimize fetal health outcomes and reduce pregnancy-related risks.

INTRODUCTION

The placenta is a highly intricate and crucial organ during pregnancy, with its functions being vital for proper fetal development. As a villous haemochorial organ, it plays a pivotal role in not only transferring nutrients to the developing fetus but also acting as both a metabolic and endocrine organ. These functions are essential for sustaining and promoting fetal growth throughout the pregnancy. Maternal anaemia, a prevalent condition during pregnancy, can have profound effects on both maternal and fetal well-being. One of the main consequences of maternal anaemia is fetal hypoxemia, which arises from inadequate oxygen delivery to the fetus.

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This oxygen deficiency can trigger compensatory mechanisms in the placenta, often resulting in placental hypertrophy, or the enlargement of the placenta. This adaptation likely serves to enhance oxygen supply to the fetus despite the reduced oxygen-carrying capacity of the mother's blood. The World Health Organization (WHO) defines anaemia during pregnancy as a haemoglobin level below 11 gm/dl [1]. Investigating the link between maternal anaemia and placental changes is crucial, as these alterations can significantly influence fetal health outcomes. A thorough examination of the placenta in such cases may uncover specific morphological and functional changes that are associated with maternal conditions like anaemia. Such insights could prove valuable in forecasting fetal outcomes and informing clinical strategies for managing pregnancy complications.

MATERIALS AND METHODS

The study was conducted within the Department of Biochemistry at PSP Medical College and Hospitals, Oragadam, Chennai, Tamil Nadu, India, in 2023. A total of 150 placentae were examined, with 120 cases from anaemic pregnancies (study group) and 30 cases from normal pregnancies (control group). Placentae were collected from the labour ward and the obstetrics operation theatre. The placentae were matched to the corresponding mothers based on serial numbers.

Upon admission to the labour room, a comprehensive maternal history was recorded, including the mother's name, age, address, husband's details, occupation, menstrual history, gravidity, and parity, all gathered from clinical records. The mothers underwent a physical examination, where their height, weight, body build, and blood pressure were noted. Relevant clinical investigations, including ultrasound (USG) reports, were also documented.

Placentae, along with a 10 cm segment of the umbilical cord and associated membranes, were collected immediately after either a normal vaginal delivery or caesarean section. Any abnormalities in the cord and membranes were meticulously noted. Adherent blood clots were removed from the maternal surface, and the placentae were thoroughly washed using running tap water.

The following parameters were recorded for each placenta: weight, volume (measured using the water displacement method), diameter, average thickness, shape, number of cotyledons, presence of infarctions or calcifications, site of umbilical cord attachment, and the number of blood vessels in the umbilical cord. These observations were systematically recorded to assess the potential morphological and functional changes associated with maternal anaemia.

RESULT

The analysis of placental parameters in a study comprising 150 cases, including 70 normal pregnancies and 80 anaemic pregnancies, revealed significant differences across key metrics. The mean placental weight in anaemic pregnancies was higher (465 g) compared to normal pregnancies (432 g), with standard deviations of 69 and 70, respectively, showing statistical significance ($p<0.05$). Similarly, the mean placental volume was greater in anaemic cases (385 ml) than in normal cases (348 ml), with respective standard deviations of 62 and 55 ($p<0.05$).

The mean diameter of the placenta in anaemic pregnancies was notably larger (17.8 cm) compared to normal pregnancies (15 cm), with standard deviations of 2.1 and 1.6, respectively, indicating a statistically significant difference ($p<0.05$). While the mean placental thickness showed only a slight increase in anaemic pregnancies (2.35 cm) compared to normal pregnancies (2.3 cm), the difference was significant due to the larger variability observed in anaemic cases (SD = 0.5 vs. 0.25, $p<0.05$).

A marked difference was also observed in the number of cotyledons, with a mean of 12.7 in anaemic pregnancies compared to 15.5 in normal pregnancies, and standard deviations of 3.6 and 2.2, respectively, showing statistical significance ($p<0.05$). These findings underscore the morphological and structural adaptations of the placenta in response to maternal anaemia, reflecting compensatory mechanisms aimed at optimizing fetal oxygen and nutrient supply under compromised maternal conditions.

The investigation of placental morphometry provides valuable insights into how maternal conditions, such as anemia, can influence the development and functionality of the placenta. The results from this study, conducted with 150 cases (70 normal pregnancies and 80 with anemia), highlight significant differences in placental parameters, suggesting that anemia has a marked impact on placental growth and structure, which in turn has implications for fetal development and maternal health.

Table 1: Placental Morphological and Structural Measurements.

Parameter	Normal Mean	Normal Std. Deviation	Normal N	Anaemia Mean	Anaemia Std. Deviation	Anaemia N	Significant
Weight Pl	432	70	70	465	69	80	2.52 p<0.05
Vol. Pl	348	55	70	385	62	80	2.32 p<0.05
Mean diameter	15	1.6	70	17.8	2.1	80	2.69 p<0.05
Thickness	2.3	0.25	70	2.35	0.5	80	6.42 p<0.05
Cotyledons	15.5	2.2	70	12.7	3.6	80	4.67 p<0.05

Placental Weight

The increased placental weight observed in anemic pregnancies is consistent with the concept of placental hypertrophy, a common compensatory response to maternal anemia. Studies have consistently shown that placental weight increases in anemic pregnancies as the placenta works harder to supply oxygen and nutrients to the fetus. Research [2] supports this finding, suggesting that the placenta's increased size and weight in these cases serve as an adaptive mechanism to overcome the reduced oxygen-carrying capacity of the mother's blood. This hypertrophy reflects the placenta's efforts to enhance its function in a compromised oxygen environment, ensuring adequate nutrient exchange to support fetal growth.

Placental Volume

The significant increase in placental volume observed in the study mirrors the findings of previous research, which suggests that an increased placental volume can help offset the reduced oxygen supply in anemia by enlarging the surface area for nutrient and gas exchange. The expanded volume in anemic pregnancies likely represents a hyperplastic response, with placental tissue proliferating to compensate for the hypoxic conditions. This phenomenon has been documented in other studies, including those by Salafia et al. [5], who found that placentas from anemic pregnancies tend to have larger volumes and surface areas, enhancing the placenta's efficiency in nutrient transfer despite reduced oxygen levels.

Placental Diameter

The enlargement in placental diameter in anemic pregnancies further supports the idea of compensatory growth. The increase in diameter likely reflects a lateral expansion, aimed at increasing the surface area available for nutrient and gas exchange between the mother and fetus. Similar findings were noted by Basu et al., who reported that placentas from anemic mothers typically exhibit larger diameters. This expansion of the placenta’s surface area could be crucial for counteracting the negative effects of anemia and improving fetal outcomes by facilitating better maternal-fetal nutrient exchange.

Placental Thickness

Interestingly, the study did not find a significant difference in placental thickness between normal and anemic pregnancies. Previous studies have shown varying results regarding placental thickness in anemia, with some suggesting an increase in thickness and others showing no significant difference. The lack of difference in this study could be attributed to factors such as the severity of anemia, the timing of placental measurements, or variations in the population studied. This suggests that, in the context of maternal anemia, compensatory placental growth may be more evident in other dimensions—such as weight, volume, and diameter—rather than thickness.

Cotyledons

One of the most significant findings of this study is the reduction in the number of cotyledons in anemic pregnancies. Cotyledons are the functional units of the placenta, and a reduction in their number can impair placental function. This finding is consistent with research by Kingdom and Kaufmann, who observed that maternal anemia and other complications could lead to a decreased number of functional cotyledons, thus diminishing the placenta’s efficiency in nutrient and gas exchange. The reduction in cotyledon number could result in compromised placental function, which may contribute to adverse fetal outcomes such as intrauterine growth restriction (IUGR) [6].

Implications for Fetal and Maternal Health

The alterations in placental morphology observed in anemic pregnancies are not just structural changes but carry significant implications for both fetal and maternal health. The compensatory enlargement of the placenta in response to anemia likely helps ensure the fetus receives sufficient nutrients and oxygen. However, these compensatory changes may also indicate a stressed placental environment, which could predispose both mother and child to pregnancy-related complications. Larger placental size has been associated with an increased risk of conditions such as preeclampsia and gestational diabetes [7].

Despite the compensatory growth, the placenta may not fully mitigate the effects of anemia, and fetal outcomes can still be compromised. Studies have shown that even with an enlarged placenta, the fetus of an anemic mother may still face an increased risk of IUGR, preterm birth, and low birth weight. This emphasizes the importance of early detection and management of anemia during pregnancy. Ensuring adequate maternal iron levels and monitoring placental development can help reduce the risk of adverse outcomes and improve both maternal and fetal health [8].

The findings of this study underline the complex relationship between maternal anemia and placental changes. While the placenta may adapt to ensure fetal survival in the face of maternal anemia, these structural alterations may also signal an environment that could lead to longer-term health issues for both the mother and the child. Continued research into placental adaptations to maternal anemia and other complications is essential for improving prenatal care and outcomes.

CONCLUSION

This study highlights the significant impact of maternal anemia on placental morphology and structure, revealing key differences in placental parameters such as weight, volume, diameter, thickness, and the number of cotyledons between normal and anemic pregnancies. The findings underscore the adaptive nature of the placenta in response to maternal anemia, with compensatory mechanisms such as placental hypertrophy, increased volume, and enlarged diameter working to mitigate the effects of reduced oxygen supply to the fetus.

While these adaptations help ensure fetal survival by enhancing nutrient and oxygen exchange, they also signal potential risks to both maternal and fetal health. The reduction in the number of functional cotyledons in anemic pregnancies suggests compromised placental efficiency, which may contribute to adverse fetal outcomes like intrauterine growth restriction, low birth weight, and preterm birth. Furthermore, despite the compensatory growth in placental size, the placenta may not fully counteract the effects of anemia, highlighting the need for vigilant monitoring and management of maternal anemia during pregnancy.

The findings emphasize the critical importance of early detection, nutritional support, and medical interventions to manage anemia during pregnancy and optimize fetal health. This study also calls for continued research into the intricate relationship between maternal anemia, placental changes, and fetal outcomes, aiming to improve prenatal care and reduce the incidence of pregnancy-related complications. Addressing maternal anemia remains a vital aspect of ensuring healthy pregnancies and favorable birth outcomes.

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