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Assessment of Placental Morphometrics: A Comparison between Normal and IUGR Placentae and Their Impact on Fetal Growth

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Abstract

This study investigates the relationship between placental morphometrics and fetal growth outcomes in normal and intrauterine growth restriction (IUGR) pregnancies. We compared various placental parameters between control and IUGR groups to elucidate the structural differences associated with compromised fetal development. Our findings reveal significant disparities in placental morphology between the two groups. IUGR placentae exhibited markedly reduced weights (350-450g vs. 550-600g in controls), smaller maternal and fetal surface areas, and fewer cotyledons. Fetal weights in IUGR cases were substantially lower (1500-2440g vs. 2400-3500g in controls). Umbilical cords in IUGR pregnancies were generally shorter and slightly thinner, with less optimal insertion sites. These results underscore the critical role of placental structure in fetal growth. The observed reductions in placental size and complexity in IUGR cases likely contribute to diminished nutrient and oxygen transfer, directly affecting fetal development. This study enhances our understanding of the placental factors influencing IUGR and may inform future research on early detection and potential interventions for improved pregnancy outcomes.

Keywords: *Fetal Growth, Intrauterine Growth Restriction (IUGR), Maternal-Fetal Exchange, Placental Insufficiency, Placental Morphometrics, Umbilical Cord.*

Introduction

Placental morphometrics plays a pivotal role in understanding fetal growth and development. Complications from placental insufficiency are a major cause of adverse pregnancy outcomes worldwide, according to the World Health Organization (WHO). These complications contribute significantly to intrauterine growth restriction (IUGR), preterm births, and perinatal mortality. IUGR affects 10-15% of pregnancies globally, leading to increased risks of neonatal morbidity and long-term developmental challenges [1]. Early detection and intervention in pregnancies at risk for IUGR are crucial, and assessing placental morphology can provide critical insights. The problem addressed by this study is the need for reliable markers of placental insufficiency that can predict adverse fetal outcomes, especially in IUGR cases. While current clinical assessments such as fetal biometry and Doppler ultrasound are useful, they may not fully reflect the extent of placental pathology. This research explores placental morphometrics as a potential diagnostic tool that could offer a more accurate assessment of placental function and its impact on fetal growth.

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Existing solutions, such as fetal biometry and Doppler studies, provide insight into fetal growth but do not sufficiently address the structural characteristics of the placenta. Studies by Bhatia and Shah (2024) emphasize Doppler assessments, while Khodjamova et al. (2024) and Gumeniuk et al. (2024) focus on fetal growth and neonatal outcomes [2-4]. However, these studies overlook detailed placental morphometry, which remains an underexplored area. Morphometric analysis of placental parameters such as weight, surface area, cotyledon count, and umbilical cord length could fill this gap. The best approach for this study is a detailed morphometric comparison of normal and IUGR placentae, which aims to correlate these measurements with fetal growth outcomes. This could provide new insights into how placental insufficiency directly influences fetal development. The main limitation of current diagnostic methods is their reliance on indirect assessments of placental function. This study, by focusing on the structural analysis of the placenta, seeks to address this gap and provide more direct evidence of placental dysfunction in IUGR cases. The achievement of this study will be to enhance our understanding of the structural factors contributing to IUGR and to potentially identify predictive markers that could improve the clinical management of at-risk pregnancies. The objective of the study is to conduct a detailed morphometric analysis of normal and IUGR placentae, correlating these parameters with fetal growth outcomes. The novelty of the work lies in its focus on placental morphometrics as a diagnostic tool, which has the potential to offer a clearer understanding of IUGR and guide earlier interventions for improved pregnancy outcomes.

Materials and Methods

This study was a comparative observational study aimed at assessing the morphometric parameters of placentae from normal and intrauterine growth retardation (IUGR) pregnancies and correlating these parameters with fetal growth outcomes. The study involved detailed morphometric analysis of placentae obtained from mothers who delivered at the Sri Venkateswaraa Medical College and Research Institute, Kanchipuram. Placentae were collected from the delivery ward and transferred to the Department of Anatomy for analysis. A total of 100 human placentae were included in this study. The placentae were obtained immediately after delivery from mothers who gave birth at the hospital. Placentae from both normal pregnancies (control group) and pregnancies complicated by IUGR were included. The study was conducted following ethical guidelines and was approved by the Institutional Ethics Committee of Sri Venkateswaraa Medical College and Research Institute.

The placentae were divided into two groups: Normal Placentae (Control Group) and IUGR Placentae. The experimental procedures spanned six months, during which placental samples were collected, preserved, and analyzed for various morphometric parameters. Placentae with attached cord and membranes were collected immediately after delivery, noting any abnormalities, and preserved in a 10% formalin solution until further analysis. The morphometric analysis included several parameters: placental weight measured using a digital scale, fetal weight recorded from hospital records, maternal and fetal surface areas calculated by taking imprints on graph paper, and the number of cotyledons counted by mapping the maternal surface into 15-30 lobes using fissures or grooves. Additionally, the length of the umbilical cord was measured in centimetres using a thread, the thickness of the cord was measured using a vernier calliper, and the site of insertion of the cord was determined by calculating the insertion percentage (d/r x 100) based on the minimum distance between the insertion site and the placenta margin. This allowed the categorization of the insertion as central (76 - 100), medial (51 - 75), lateral (26 - 50), or marginal (0 - 25).

1. **Placental Weight:** Each placenta was weighed using a digital scale immediately after delivery to determine its mass. The weight of the placenta is a crucial parameter, as it has been shown to correlate with fetal weight and overall pregnancy health. Studies have highlighted that placental weight can significantly influence birth weight and may vary depending on maternal health conditions, such as hypertensive disorders.
2. **Fetal Weight:** Fetal weight was recorded from hospital records, typically obtained through standard neonatal assessments. This parameter is essential for assessing the impact of placental function on fetal growth. Research indicates a strong correlation between placental morphometry and fetal weight, with abnormalities in placental size often associated with intrauterine growth restrictions (IUGR).
3. **Maternal Surface Area:** The maternal surface area of the placenta was calculated by taking imprints of the maternal side on graph paper. This method allows for precise measurement of the area, which is crucial for understanding the extent of the placental surface available for nutrient exchange. Marques et al. (2018) emphasized the importance of maternal surface area in determining placental efficiency and its relationship with fetal growth in pregnancies complicated by hypertension.
4. **Fetal Surface Area:** Similar to the maternal surface area, the fetal surface area was calculated by taking imprints on graph paper. This measurement is essential for evaluating the interface between the placenta and the fetus, which is critical for effective nutrient and oxygen exchange. The fetal surface area can provide insights into the placenta's ability to support fetal development, particularly in compromised pregnancies.
5. **Number of Cotyledons:** Cotyledons were counted by mapping the maternal surface into 15-30 lobes using a series of fissures or grooves. The number of cotyledons, which are the functional units of the placenta, is indicative of the organ's structural complexity and its capacity for nutrient exchange. Anomalies in cotyledon number or structure can lead to impaired placental function, potentially resulting in adverse pregnancy outcomes such as low birth weight.
6. **Length of Umbilical Cord:** The length of the umbilical cord was measured in centimetres using a thread. The umbilical cord length is a critical parameter that can influence fetal movement and nutrient delivery. Abnormal cord length, whether too short or too long, can be associated with complications such as restricted fetal growth or delivery issues. Studies have shown that cord length, in conjunction with placental size and function, can provide a comprehensive understanding of fetal well-being.
7. **Thickness of the Cord:** The thickness of the umbilical cord was measured using a vernier calliper. Cord thickness can indicate the robustness of the vascular structures within the cord, which are vital for nutrient and oxygen transport to the fetus. A thickened cord might suggest issues such as oedema or excessive Wharton's jelly, while a thin cord could indicate underdevelopment or reduced blood flow capacity.
8. **Site of Insertion of the Cord:** The site of insertion of the umbilical cord was assessed by measuring the minimum distance between the insertion site and the placental margin (denoted as 'd'). This was then compared to the mean radius (r) of the placenta to calculate the insertion percentage (d/r x 100). Based on this

percentage, the cord insertion was categorized as central (76 - 100), medial (51 - 75), lateral (26 - 50), or marginal (0 - 25). The site of cord insertion is crucial for understanding the distribution of blood flow within the placenta. Abnormal insertions, such as marginal or velamentous, are associated with increased risks of adverse outcomes, including IUGR and preterm birth.

Statistical Analysis

Data were analyzed using statistical software (e.g., SPSS). Descriptive statistics were used to summarize the data. Comparisons between normal and IUGR placentae were made using t-tests or Mann-Whitney U tests, as appropriate. Correlation analyses were performed to assess the relationship between placental morphometric parameters and fetal growth outcomes. A significance level of $p < 0.05$ was set for all statistical tests.

Results

The demographic details of the study population, including maternal age, parity, and gestational age, were recorded for both the normal (control) (80 Placentae) and IUGR groups (20 Placentae). The experimental procedures were conducted over six months, during which placental samples were collected immediately after delivery. Each placenta, with attached cord and membranes, was examined for any abnormalities, and then preserved in a 10% formalin solution for subsequent morphometric analysis.

The morphometric analysis involved several key parameters such as

1. **Placental Weight:** Placental weight in the IUGR group was markedly lower than in the control group. Normal placentae averaged between 550 and 600 grams, whereas IUGR placentae were significantly lighter, averaging between 350 and 450 grams (Table 1). This substantial reduction in placental weight in the IUGR group suggests impaired placental growth and function, which is likely a key factor in the restricted fetal development observed in these pregnancies (Figures 1 & 2).
2. **Fetal Weight:** Fetal weights also exhibited notable differences between the groups. Control fetuses weighed between 2400 and 3500 grams, while IUGR fetuses were significantly lighter, ranging from 1500 to 2440 grams (Table 1). This disparity underscores the direct impact of placental insufficiency on fetal growth, as the compromised placental function in the IUGR group limits the nutrient and oxygen supply necessary for normal fetal development.
3. **Maternal Surface Area:** The maternal surface area of placentae was larger in the control group, ranging from 200 to 305 cm^2, compared to the IUGR group, which ranged from 96 to 200 cm^2 (Table 1). The reduced maternal surface area in IUGR placentae indicates a diminished capacity for maternal-fetal exchange, likely contributing to the restricted growth of the fetus by limiting the delivery of essential nutrients and oxygen (Figures 1 & 2).
4. **Fetal Surface Area:** Fetal surface area measurements followed a similar trend. Control placentae had larger surface areas, from 171 to 300 cm^2, while IUGR placentae had smaller areas, from 88 to 200 cm^2 (Table 1). This reduction in surface area in IUGR cases suggests insufficient villous development, which can result in reduced gas and nutrient exchange, exacerbating fetal growth restriction (Figure 1 & 2).
5. **Number of Cotyledons:** The number of cotyledons, which are the functional units of the placenta, was generally higher in the control group (10 to 27) compared to the IUGR group (8 to 15). Fewer cotyledons in IUGR placentae indicate less efficient placental function and structure,

contributing to the compromised support for the developing fetus.

6. **Length of Umbilical Cord:** The length of the umbilical cord varied widely in the control group (20 to 62 cm), while it was more consistent and shorter in the IUGR group (29 to 38 cm). Shorter umbilical cords in IUGR pregnancies may reflect restricted fetal movement and reduced amniotic fluid volume, both of which are associated with adverse fetal growth outcomes (Table 2).
7. **Thickness of the Cord:** The thickness of the umbilical cord in the IUGR group was slightly thinner, averaging 0.8 to 2.0 cm, compared to 0.7 to 2.0 cm in the control group (Table 2). Thinner cords in IUGR cases may suggest compromised vascular development within the cord, impacting the efficiency of nutrient and oxygen transport to the fetus (Figure 2).
8. **Site of Insertion of the Cord:** The site of insertion of the umbilical cord was more optimal (central or medial) in control placentae, whereas IUGR placentae often had less optimal (marginal or lateral) insertions. Marginal and lateral insertions can lead to suboptimal placental perfusion and nutrient delivery, further contributing to fetal growth restriction.

Table 1. Comparison of Placental Morphometric Parameters between Control and IUGR Groups

Parameter Name	**Control Group (Mean ± SD)**	**IUGR Group (Mean ± SD)**	**'t' Value**
Placental Weight (g)	567.2 ± 68.64	398.2 ± 59.77	0.00
Fetal Weight (g)	2796 ± 213.7	2023 ± 316.5	0.00
Maternal Surface Area (cm²)	244.75 ± 42.58	140.9 ± 35.90	0.00
Fetal Surface Area (cm²)	239.9 ± 45.09	140.9 ± 33.11	0.00
Number of Cotyledons	14.8 ± 4.34	10.3 ± 2.05	0.00

The Values are Expressed as the Mean ± Standard Deviation. The 't' Values Indicate the Statistical Significance of the Differences Observed between the Two Groups.

Table 2. Comparison of Umbilical Cord Length and Thickness between Control and IUGR Groups

Parameter Name	**Control Group (Mean ± SD)**	**IUGR Group (Mean ± SD)**	**'t' Value**
Length of Umbilical Cord (cm)	30.2 ± 6.40	33.6 ± 2.23	0.65
Thickness of Umbilical Cord (cm)	1.46 ± 0.40	1.49 ± 0.68	0.55

The Values are Reported as Mean ± Standard Deviation. The 't' Values Represent the Statistical Significance of the Differences Between the Control and IUGR Groups.

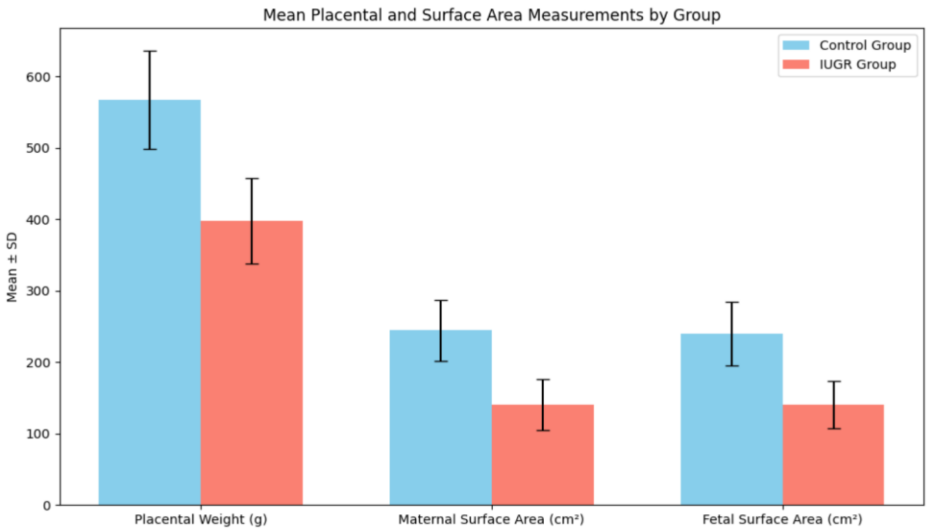

Figure 1: Graph Showing Morphometry Measurement of Placentae

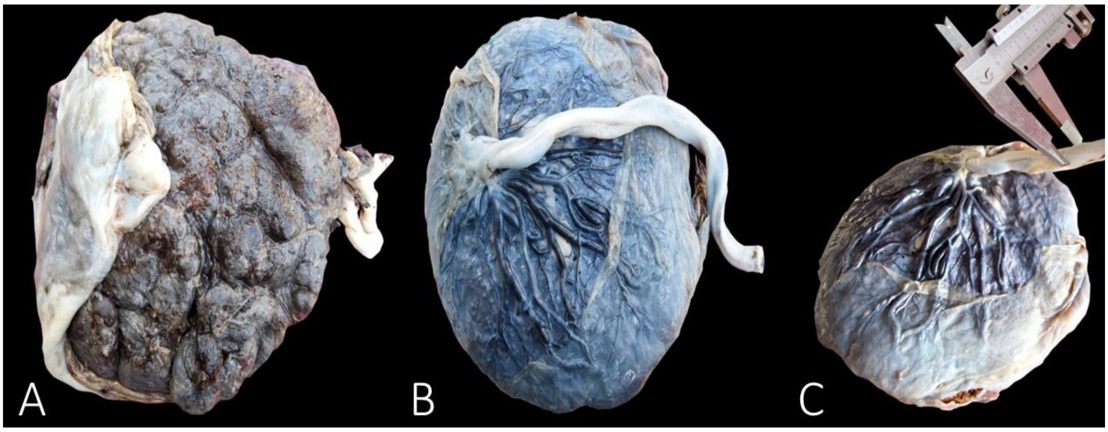

Figure 2: Showing Features and Measurement of Placenta (A – Maternal Surface, B – Foetal Surface, C – Measuring the Thickness of the Umbilical Cord)

Discussion

The present study provides a comprehensive analysis of placental morphometrics by comparing normal placentae with those from pregnancies complicated by intrauterine growth restriction (IUGR). The study's findings reveal significant differences in key parameters such as placental weight, fetal weight, maternal and fetal surface areas, number of cotyledons, and umbilical cord length between the two groups, which may have crucial implications for understanding the pathophysiology of IUGR. The most striking finding was the substantial reduction in placental weight in the IUGR group compared to the control group. The average placental weight in normal pregnancies ranged from 550 to 600 grams, whereas in IUGR cases, it was significantly lower, between 350 and 450 grams. This reduction in placental weight is consistent with the findings of Tankala et al. (2023), who also reported significantly lower placental weights in IUGR cases [5, 6]. The decreased placental weight likely reflects impaired placental growth and function, which is crucial for supporting fetal development. The reduced weight in the IUGR group can be attributed to insufficient placental vascularization and nutrient transfer, which directly impacts fetal growth. Similarly, fetal weight was notably lower in the IUGR group, with fetuses weighing between 1500 and 2440 grams compared to 2400 to 3500 grams in the control group. This finding aligns with the study by Deshpande (2024), who observed a direct correlation between reduced placental size and lower birth weights in IUGR pregnancies [7]. The significant difference in fetal weight underscores the critical role of the placenta in fetal development, where compromised placental function directly translates to restricted fetal growth. In this study, significant differences in placental morphometrics between normal and IUGR placentae highlight the critical role of placental structure in fetal growth. The findings align with Rajeev et al. (2020), who demonstrated a positive correlation between placental size and birth weight, emphasizing the impact of placental insufficiency on fetal outcomes [8]. Sharma et al. (2017) similarly associated impaired placental function with intrauterine growth restriction (IUGR) [9]. Additionally, demographic factors and clinical history, as outlined by Kondor et al. (2020), may further influence these outcomes [10]. These results underscore the need for early screening of placental morphology to mitigate IUGR-related complications.

The maternal and fetal surface areas of the placentae also demonstrated significant differences. In the control group, the maternal surface area ranged from 200 to 305 cm^2, while in the IUGR group, it ranged from 96 to 200 cm^2. The fetal surface area exhibited a similar trend, with normal placentae showing larger surface areas (171 to 300 cm^2) compared to IUGR placentae (88 to 200 cm^2). These findings are consistent with the study by Govender et al. (2022), Abdurasulovich & Izzatullaevna (2024) and Beloosesky et al (2024), which highlighted the importance of the placental surface area in facilitating adequate maternal-fetal exchange [11-13]. The reduced surface area in IUGR placentae suggests a diminished capacity for nutrient and gas exchange, contributing to fetal growth restriction. The number of cotyledons, which are the functional lobes of the placenta, was also reduced in the IUGR group. While the control group exhibited 10 to 27 cotyledons, the IUGR group had fewer, ranging from 8 to 15. This reduction in cotyledon number is indicative of impaired placental structure and function, which correlates with the findings of de Souza Lima et al (2024), Emeka-Ogbugo et al (2024) and Parker et al. (2024), who observed similar reductions in cotyledon count in cases of intrauterine fetal death [14-16]. The length of the umbilical cord also varied significantly between the groups. In the control group, the cord length ranged widely from 20 to 62 cm, while in the IUGR group, it was more consistent and shorter, ranging from 29 to 38 cm. This finding is consistent with studies by Orzel et al. (2024) and Wu et al (2024), which noted that shorter umbilical cords are often associated with restricted fetal movement and reduced amniotic fluid volume, both of which are linked to adverse fetal outcomes. The shorter cord length in IUGR pregnancies could reflect these underlying issues, further contributing to the compromised fetal growth observed in these cases [17, 18].

The observed differences in placental morphometrics between the normal and IUGR groups can be attributed to several molecular and developmental factors. Placental insufficiency in IUGR is often associated with impaired trophoblast invasion and abnormal placental vascularization, leading to reduced placental size and function. The reduced number of cotyledons and smaller surface areas in IUGR placentae may result from inadequate villous development and branching, which limits the placenta's ability to support the growing fetus. Intrauterine growth restriction (IUGR) is linked to significant alterations in placental morphometry due to molecular and developmental disruptions. Research suggests that reduced trophoblast syncytialization, a key process for nutrient and oxygen exchange, contributes to impaired fetal growth in IUGR pregnancies [19, 20]. Placental apoptosis also plays a central role, as increased apoptotic markers correlate with smaller placental size and abnormal morphology. Moreover, maternal malnutrition has been shown to impair placental transporter expression, disrupting nutrient transfer and fetal development [21, 22]. These morphometric abnormalities align with the concept that the molecular development of the placenta is crucial in preventing growth restriction, as noted by Putra et al (2022) [23]. Collectively, these findings emphasize that both genetic programming and environmental stressors shape placental structure, which directly impacts fetal outcomes. Early detection of these morphometric changes could guide timely interventions to improve fetal growth and reduce IUGR complications.

This study's strengths lie in its comprehensive analysis of placental morphometrics and its correlation with fetal growth outcomes. By including a relatively large sample size and using standardized measurement techniques, the study provides robust data that contribute to the existing knowledge of the placental function and its impact on fetal development. However, the study has some limitations, including its cross-sectional design, which limits the ability to infer causality. Additionally, the study did not account for potential confounding factors such as maternal health, socioeconomic status, and environmental influences, which may affect placental development and fetal growth.

Conclusion

This study underscores the pivotal role of placental morphometrics in determining fetal growth outcomes. The significant differences observed between normal and IUGR placentae reinforce the importance of early identification and management of placental insufficiency to improve fetal development and reduce adverse outcomes. The findings suggest that detailed morphometric evaluations can provide valuable insights for predicting growth restrictions in utero. Given the critical nature of placental structure in fetal growth, incorporating these assessments into routine clinical practice could enhance the detection of high-risk pregnancies. Future research should focus on longitudinal studies to establish causal relationships between placental development and fetal outcomes. Furthermore, investigating the molecular pathways contributing to placental insufficiency may offer novel therapeutic targets to prevent or mitigate IUGR. By addressing these aspects, we can contribute to more effective management strategies for improving both perinatal and long-term health outcomes in affected pregnancies.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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