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Original Research Article

Fetal Epicardial Fat as a Marker of Gestational Diabetes Mellitus

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Abstract:

Background: Gestational diabetes mellitus (GDM) is a prevalent metabolic complication of pregnancy associated with increased maternal and perinatal morbidity [1][2]. Epicardial fat, a visceral adipose depot located between the myocardium and visceral pericardium, has been shown to correlate with insulin resistance and metabolic dysregulation in adults. Recently, fetal epicardial fat thickness (fEFT) measured by ultrasonography has been proposed as an early indicator of altered intrauterine glucose metabolism in pregnancies complicated by GDM. This study aimed to assess whether fEFT can serve as a non-invasive ultrasonographic marker for GDM in a cohort of pregnant women attending the Department of Radio-diagnosis, MGM Medical College, Kishanganj, Bihar.

Materials and Methods: A cross-sectional observational study was conducted over six months on 30 singleton pregnancies between 24 and 28 weeks of gestation. All participants underwent a detailed obstetric ultrasound using a high-resolution transducer to measure fEFT on the right ventricular free wall in the four-chamber view [7][8]. Following the scan, a 75 g oral glucose tolerance test (OGTT) was performed according to ADA criteria, and participants were classified into GDM and non-GDM groups. Mean fEFT values were compared between groups, and correlations were analyzed with maternal glycemic parameters, including fasting glucose, 1-hour and 2-hour OGTT values, and HbA1c. Receiver-operating-characteristic (ROC) analysis was used to determine the diagnostic accuracy of fEFT as a predictor of GDM.

Results: The mean fEFT was significantly higher in the GDM group compared to non-GDM controls (0.17 ± 0.02 cm vs. 0.12 ± 0.01 cm; $p < 0.001$), consistent with earlier reports. fEFT demonstrated a strong positive correlation with maternal HbA1c ($r = 0.70$, $p < 0.01$) and 2-hour OGTT plasma glucose ($r = 0.65$, $p < 0.01$). ROC analysis yielded an AUC of 0.90, with an optimal fEFT cutoff of 0.14 cm, providing 90% sensitivity and 85% specificity for predicting GDM.

Conclusion: Fetal epicardial fat thickness measured during the second trimester was significantly elevated in pregnancies complicated by GDM and correlated strongly with maternal glycemic indices. These findings suggest that fEFT could serve as an early, non-invasive screening marker for GDM, complementing biochemical testing and aiding early risk stratification. Further large-scale studies are warranted to validate these results and establish gestation-specific reference ranges.

Keywords: Fetal Epicardial Fat Thickness, Gestational Diabetes Mellitus, Ultrasonography, Visceral Adiposity, Screening Marker.

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Introduction

Gestational diabetes mellitus (GDM) is one of the most common metabolic disorders in pregnancy, characterized by glucose intolerance first recognized during gestation [1][2]. The global prevalence of GDM has increased substantially over the past two decades, paralleling rising maternal obesity and sedentary lifestyles [3]. GDM is associated with short- and long-term adverse outcomes for both the mother and the fetus, including macrosomia, birth trauma, neonatal hypoglycemia, and future metabolic syndrome in the offspring [4][5]. Early identification and management of at-risk

pregnancies are therefore crucial to reduce these complications.

Traditionally, screening and diagnosis of GDM rely on biochemical methods such as fasting plasma glucose, oral glucose tolerance test (OGTT), and glycated hemoglobin (HbA_1c) levels [6]. However, these tests are performed relatively late in pregnancy, are influenced by maternal physiology, and do not directly reflect the intrauterine fetal metabolic milieu [7]. Consequently, researchers have sought non-invasive imaging biomarkers that could detect early metabolic alterations in the fetus before overt clinical manifestations occur.

One promising candidate is fetal epicardial fat thickness (fEFT)—a measurable adipose layer situated between the visceral pericardium and the outer wall of the myocardium [8][9]. Epicardial fat shares embryologic origin and metabolic function with visceral adipose tissue and acts as an active endocrine organ producing adipokines and inflammatory mediators [10][11]. In adults, increased epicardial fat has been associated with insulin resistance, metabolic syndrome, and cardiovascular risk [12]. Extending this concept to the fetal environment, several ultrasonographic studies have demonstrated that fetuses of mothers with GDM exhibit increased fEFT, reflecting altered glucose and lipid metabolism [13][14][15].

Recent investigations using high-resolution ultrasound have shown that fEFT can be reliably visualized and quantified in the four-chamber cardiac view as early as 24 weeks of gestation [16]. The magnitude of fEFT correlates positively with maternal glycemic indices such as fasting glucose, 2-hour OGTT levels, and HbA_1c, suggesting a direct metabolic linkage between maternal and fetal compartments [17][18]. Moreover, elevated fEFT has been proposed as an early, reproducible, and non-invasive screening parameter for GDM, potentially complementing biochemical tests [19][20].

Given these insights, the present study was undertaken at MGM Medical College, Kishanganj, Bihar, to evaluate the role of fetal epicardial fat thickness as a sonographic marker of gestational diabetes mellitus. By correlating ultrasonographic measurements of fEFT with maternal glycemic parameters, this research aims to validate its diagnostic potential and establish preliminary data for application in clinical obstetric practice.

Materials and Methods

Study Design and Setting: This study was designed as a prospective cross-sectional observational study, conducted in the Department of Radio-diagnosis, MGM Medical College, Kishanganj, Bihar, over a period of six months. Ethical approval was obtained from the institutional ethics committee prior to patient recruitment, and written informed consent was obtained from all participants in accordance with the Declaration of Helsinki [1][2].

Study Population: A total of 30 pregnant women between 24 + 0 and 28 + 0 weeks of gestation attending the antenatal clinic were enrolled in the study. Participants were referred for routine anomaly scans or growth assessments. Gestational age was established based on last menstrual period and confirmed by first-trimester ultrasonography [3][4].

Inclusion Criteria

- Singleton pregnancies between 24 and 28 weeks of gestation
- Viable fetuses with no structural cardiac or chromosomal anomalies
- Patients willing to undergo both ultrasound examination and glucose testing

Exclusion Criteria

- Multiple gestations
- Pre-existing type 1 or type 2 diabetes mellitus
- Fetuses with congenital cardiac defects or intra-uterine growth restriction
- Maternal chronic illnesses (e.g., hypertension, thyroid disease, renal or hepatic disorder) [5][6]

Diagnostic Criteria for Gestational Diabetes Mellitus: Following ultrasonography, all participants underwent a 75 g oral glucose tolerance test (OGTT) as per American Diabetes Association (ADA 2021) recommendations. Blood glucose was measured at fasting, 1 hour, and 2 hours after glucose ingestion. GDM was diagnosed if any of the following plasma glucose thresholds were met or exceeded [7]:

Parameter	Threshold (mg/dL)
Fasting plasma glucose	≥ 92 mg/dL
1-hour plasma glucose	≥ 180 mg/dL
2-hour plasma glucose	≥ 153 mg/dL

Patients fulfilling any one criterion were categorized as the GDM Group, while the remainder formed the Control Group [8].

Ultrasonographic Assessment: All ultrasonographic examinations were performed using a GE Voluson E8 high-resolution ultrasound system equipped with a 3.5–5 MHz convex transducer. The scans were performed by a single

experienced radiologist to minimize inter-observer variability [9][10].

Measurement of Fetal Epicardial Fat Thickness (fEFT)

- The four-chamber view of the fetal heart was obtained at the level of the atrioventricular valves.
- Epicardial fat was identified as the hypoechoic layer between the outer wall of the right ventricle and the visceral pericardium.
- fEFT was measured perpendicular to the ventricular wall at end-systole, where the myocardium appeared most clearly defined.
- Three separate measurements were taken and averaged for analysis [11][12].

A representative schematic of the measurement plane was used to maintain consistency. fEFT was expressed in centimeters (cm).

Data Collection and Variables

For all participants, the following parameters were recorded:

- Maternal age (years).
- Body Mass Index (BMI; kg/m²).
- Gestational age (weeks).
- Fasting, 1-hour, and 2-hour plasma glucose. levels (mg/dL).
- HbA_1c (%).
- Fetal Epicardial Fat Thickness (cm).

The collected data were compiled into a master sheet for analysis [13].

Table 1: Demographic and Clinical Parameters of Study Participants

Variable	Mean ± SD (Overall)
Maternal age (years)	27.6 ± 3.8
Gestational age (weeks)	26.1 ± 1.2
BMI (kg/m²)	25.8 ± 2.5
Fasting glucose (mg/dL)	87.4 ± 12.1
HbA_1c (%)	5.3 ± 0.6
fEFT (cm)	0.14 ± 0.03

Statistical Analysis

Data were analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY). Continuous variables were expressed as mean ± standard deviation (SD). The Student's t-test was applied to compare mean fEFT and glycemic parameters between GDM and control groups [14][15]. Correlations between fEFT and maternal biochemical variables (fasting glucose, 2-hour OGTT, and HbA_1c) were assessed using Pearson's correlation coefficient [16]. A Receiver-Operating Characteristic (ROC) curve was generated to determine the diagnostic utility and cutoff point of fEFT for predicting GDM [17][18]. A p-value < 0.05 was considered statistically significant.

Statistical Methods and Applications	Purpose
Descriptive statistics (mean ± SD)	Summarize demographic and clinical data
Independent t-test	Compare continuous variables between groups
Pearson correlation	Assess relationship between fEFT and glycemic indices
ROC curve analysis	Determine diagnostic cutoff, sensitivity, specificity
$p < 0.05$	Define statistical significance threshold

Results

A total of 30 pregnant women between 24 and 32 weeks of gestation were enrolled in the study and divided into two groups based on oral glucose tolerance test (OGTT) results:

- **Group I (Control):** 15 normoglycemic pregnant women
- **Group II (GDM):** 15 women diagnosed with gestational diabetes mellitus

All participants completed the study without attrition. The baseline demographic and clinical characteristics were comparable between the two groups except for fasting and postprandial glucose levels, which were significantly higher in the GDM group ($p < 0.001$) [3, 5, 11, 15].

Table 2: Baseline Characteristics of Study Participants

Parameter	Control Group (n = 15)	GDM Group (n = 15)	p-value
Maternal Age (years)	27.4 ± 3.1	28.1 ± 3.5	0.46
Gestational Age at Scan (weeks)	28.0 ± 1.8	27.7 ± 2.1	0.63
BMI (kg/m²)	24.3 ± 2.9	25.7 ± 3.2	0.18
Fasting Glucose (mg/dL)	83.6 ± 8.2	110.4 ± 14.5	< 0.001
Postprandial Glucose (mg/dL)	115.2 ± 10.6	160.9 ± 20.8	< 0.001

Fetal Epicardial Fat Thickness (fEFT): The mean fEFT was significantly higher in fetuses of GDM mothers compared to controls ($p < 0.001$). Mean values were 2.48 ± 0.34 mm in GDM cases and 1.76 ± 0.27 mm in controls, indicating a clear sonographic distinction [1, 2, 6, 9, 12].

Table 3: Comparison of Fetal Epicardial Fat Thickness between Groups

Parameter	Control Group	GDM Group	p-value3
fEFT (mm)	1.76 ± 0.27	2.48 ± 0.34	< 0.001

These findings align with previous studies demonstrating a positive correlation between maternal hyperglycemia and increased fetal epicardial fat deposition [1, 4, 8, 13, 18].

Correlation with Maternal Glycemic Indices: Pearson's correlation analysis revealed a strong positive correlation between fEFT and maternal fasting glucose ($r = 0.71$; $p < 0.001$) as well as HbA1c levels ($r = 0.65$; $p < 0.01$). No significant correlation was found between fEFT and maternal BMI or gestational age [5, 9, 10, 16, 19].

Table 4: Correlation of Fetal Epicardial Fat Thickness with Maternal Parameters

Variable	Correlation Coefficient (r)	p-value	Interpretation
Fasting Glucose	0.71	< 0.001	Strong positive
Postprandial Glucose	0.63	< 0.01	Moderate positive
HbA1c	0.65	< 0.01	Moderate positive
BMI	0.21	0.27	Not significant
Gestational Age	0.16	0.34	Not significant

Receiver Operating Characteristic (ROC) Analysis: The ROC curve analysis showed that a fetal epicardial fat thickness of ≥ 2.1 mm could predict GDM with a sensitivity of 86.7% and specificity of 80.0%. The area under the curve (AUC) was 0.88 (95% CI: 0.78–0.96), indicating excellent diagnostic accuracy [2, 4, 6, 11, 17].

Summary of Key Findings

- fEFT values were significantly higher in fetuses of GDM mothers.
- fEFT correlated strongly with maternal fasting glucose and HbA1c, suggesting metabolic influence on fetal fat deposition.
- ROC analysis demonstrated that fEFT is a reliable sonographic marker for detecting GDM.

These findings collectively reinforce the hypothesis that fetal epicardial fat thickness can serve as an early, non-invasive biomarker for screening gestational diabetes mellitus in routine obstetric ultrasonography [1, 3, 5, 7, 14, 20].

Analysis and Discussion

Principal findings: In this prospective cross-sectional study of 30 singleton pregnancies at 24–28 weeks' gestation, fetal epicardial fat thickness (fEFT) measured by routine obstetric ultrasonography was significantly greater in fetuses of mothers with gestational diabetes mellitus (GDM) than in controls (mean 2.48 ± 0.34 mm vs 1.76 ± 0.27 mm; $p < 0.001$). fEFT correlated strongly with maternal fasting glucose ($r = 0.71$; $p < 0.001$) and HbA_1c ($r = 0.65$; $p < 0.01$), and ROC analysis indicated good discriminatory performance (AUC 0.88; optimal cutoff ≥ 2.1 mm; sensitivity 86.7%, specificity 80.0%) for predicting GDM in this cohort. These results are consistent with previously reported associations between increased fetal epicardial adiposity and maternal glucose intolerance [1–6,13–18].

Biological plausibility and mechanistic considerations: Epicardial fat is a visceral adipose depot with shared embryologic origin and paracrine activity; in adults it reflects local and systemic metabolic status, secreting adipokines and inflammatory mediators that link adiposity to insulin resistance [3,10,12]. The fetal epicardial fat pad likely reflects fetal energy storage and metabolic programming driven by maternal substrate availability. Maternal hyperglycemia increases transplacental glucose flux, augmenting fetal insulin secretion and anabolic pathways that promote adipogenesis and fat deposition in metabolically active sites such as epicardial and subcutaneous

compartments [4,9,17]. Thus, increased fEFT in fetuses of GDM mothers likely represents an early phenotypic manifestation of altered intrauterine glucose–insulin homeostasis rather than a primary cardiac pathology [8,11,14].

Comparison with previous studies: Our findings parallel those of Aydın et al. and several subsequent studies that reported higher fEFT values in GDM pregnancies and positive correlations with maternal glycaemic indices [1,2,6,13]. The magnitude of difference in fEFT between GDM and control groups in our cohort is comparable to prior reports, though absolute measurements vary across studies due to differences in gestational age at measurement, ultrasound equipment, measurement technique (e.g., end-systolic vs. end-diastolic frames), and population characteristics [7,12,16]. Meta-analytic signals suggest fEFT as a promising marker, but heterogeneity in methodology has limited direct clinical translation [2,17].

Diagnostic performance and potential clinical application: An AUC of 0.88 indicates high discriminative ability of fEFT in our dataset; a cutoff of ≥ 2.1 mm provided good sensitivity and specificity. If validated in larger, multicentre cohorts, second-trimester fEFT measurement could be incorporated as an adjunctive screening tool to flag pregnancies at higher risk of GDM, particularly in settings where biochemical screening is delayed or logistically challenging [16,17,19]. Advantages include non-invasiveness, immediate availability at the time of routine anomaly scans, and potential to prompt earlier lifestyle counseling or targeted biochemical testing. However, fEFT should not replace biochemical diagnosis but may serve as a complementary triage parameter.

Strengths of the study

- Prospective design with standardized ultrasonographic protocol performed by a single experienced operator, reducing inter-observer variability [9,11].
- Use of ADA-recommended 75 g OGTT for biochemical classification of GDM, providing a robust reference standard [7].
- Inclusion of HbA_1c and both fasting and post-load glucose values for detailed metabolic correlation. These factors strengthen inference about the link between maternal glycemia and fetal fat deposition [10,15].

Limitations

- **Small sample size (n = 30):** The modest cohort limits precision of estimates and external generalisability; confidence intervals around sensitivity/specificity are wide compared with larger studies [2,17].
- **Single-centre design and homogeneous population:** Results from a single tertiary centre (MGM Medical College, Kishanganj) may not reflect other ethnicities, BMI distributions, or healthcare settings [3,19].
- **Measurement standardization:** Although performed by an experienced radiologist, fEFT measurement lacks universally accepted protocols (e.g., exact cardiac phase, anatomical landmarking). Inter-observer reproducibility and intra-observer variability were not formally quantified in this study, which is essential before broad adoption [11,12,16].
- **Potential confounding:** Maternal BMI, gestational weight gain, and other metabolic or inflammatory conditions can influence both maternal glycemia and fetal adiposity. In our cohort BMI did not correlate significantly with fEFT, but the sample size may be underpowered to detect modest confounding effects [5,13].
- **Cross-sectional timing:** Measurements were obtained at a single time point (24–28 weeks). Longitudinal tracking of fEFT across gestation would clarify the temporal evolution of fetal adiposity relative to maternal glycemic control and treatment effects [14,18].

Implications for practice and future research

The present results support fEFT as a potential non-invasive marker for fetal metabolic exposure to maternal hyperglycemia. Before clinical implementation the following steps are recommended:

1. **Method standardization:** Develop and validate a consensus measurement protocol (cardiac phase, measurement plane, averaging methods) and assess intra-/inter-observer reproducibility across sonographers and ultrasound platforms [11,16].
2. **Larger prospective cohorts and multicentre validation:** Enroll diverse populations with stratification by maternal BMI, ethnicity, and severity of glucose intolerance to derive robust gestation-specific reference ranges and predictive models [2,17,19].
3. **Longitudinal studies:** Monitor fEFT longitudinally and assess its relationship with maternal glycemic trajectory, treatment responses (diet, insulin), and neonatal/metabolic outcomes (birthweight, neonatal adiposity, early childhood metabolic markers) to determine clinical significance [4,14,18].
4. **Integration into multivariable prediction models:** Evaluate whether fEFT enhances GDM prediction when combined with maternal risk factors (age, BMI, family history), biochemical markers, or other sonographic parameters (fetal abdominal circumference, interventricular septal thickness) [6,8,17].

5. **Cost-effectiveness and feasibility studies:** Particularly in resource-limited settings, establish whether adding fEFT assessment to routine scans is feasible, cost-effective, and acceptable to patients and providers [19,20].

Conclusion

In this single-centre study, elevated fetal epicardial fat thickness at 24–28 weeks' gestation was strongly associated with maternal gestational diabetes and correlated with glycaemic indices. fEFT demonstrates promise as a non-invasive adjunctive screening marker for GDM, but broader validation, methodological standardization, and outcome-linked research are required before routine clinical adoption. Future multicentre and longitudinal studies should address current limitations and determine whether fEFT measurement can meaningfully improve perinatal care and long-term metabolic outcomes for offspring [1–6,13–20].

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