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Research Article

Evaluation of Doppler ultrasound assessment as a Prognostic Tool in gestational diabetes

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Abstract

Background: Glycemic control alone does not fully explain which GDM pregnancies progress to macrosomia or other adverse perinatal outcome, prompting interest in Doppler indices as adjunct prognostic markers.

Objective: To determine whether third-trimester umbilical artery, uterine artery and cerebroplacental ratio (CPR) Doppler indices independently predict adverse perinatal outcome in GDM, and whether a combined Doppler score adds discriminative value.

Methods: In a prospective cohort of singleton GDM pregnancies, umbilical, uterine and middle cerebral artery Doppler indices were obtained at 34-37 weeks and related to a composite outcome of macrosomia, non-reassuring caesarean delivery, low Apgar score, hypoglycemia or NICU admission by adjusted logistic regression.

Results: Umbilical artery pulsatility index above the 95th centile (adjusted OR 3.4, 95% CI 1.6-7.2) and CPR below the 5th centile (adjusted OR 2.9, 95% CI 1.3-6.5) were independently associated with the composite outcome, and a combined Doppler score raised the AUC from 0.66 to 0.79.

Conclusions: Third-trimester Doppler assessment identifies a physiologically distinct, higher-risk subgroup of GDM pregnancies not fully captured by glycemic control or biometry alone, supporting its use as a complementary prognostic tool.

Keywords: gestational diabetes; Doppler ultrasound; umbilical artery; cerebroplacental ratio; perinatal outcome

1. Introduction

Gestational diabetes mellitus (GDM) complicates a substantial proportion of pregnancies worldwide and remains one of the strongest modifiable determinants of adverse perinatal outcome. The Hyperglycemia and Adverse Pregnancy Outcomes (HAPO) study established a continuous, threshold-free relationship between maternal glycemia and complications such as macrosomia, caesarean delivery, neonatal hypoglycemia and shoulder dystocia, without an obvious glycemic cut-point below which risk disappeared [1]. That finding, together with subsequent randomized evidence that treating even mild glucose intolerance reduces serious perinatal morbidity, reshaped screening and management guidelines internationally [2,3,4]. Yet glycemic control alone does not fully explain which GDM pregnancies will progress to macrosomia, polyhydramnios, or unexplained stillbirth, prompting sustained interest in placental and fetal hemodynamic markers that might refine risk stratification beyond glucose values alone [5,6].

Doppler ultrasonography of the uteroplacental and fetoplacental circulations has been used for four decades to characterize placental vascular resistance and fetal cardiovascular adaptation. Waveform analysis of the umbilical artery, uterine arteries and fetal middle cerebral artery (MCA) was first validated as a marker of placental insufficiency and growth restriction [7,8,9], and abnormal or absent end-diastolic flow in the umbilical artery was subsequently shown to predict adverse perinatal outcome with high specificity [10,11]. The cerebroplacental ratio, which combines umbilical artery and MCA indices, was developed to detect the early, subtle redistribution of fetal blood flow that precedes overt growth restriction, and has repeatedly outperformed either vessel alone in identifying fetuses at risk near term [12,13,14,15]. Systematic reviews of uterine artery Doppler in unselected and high-risk pregnancies further established its value for predicting placental-mediated complications, principally preeclampsia and growth restriction [16,17], leading

professional bodies to endorse Doppler assessment as a routine adjunct in complicated pregnancy [18,19].

Diabetic pregnancy occupies an unusual position in this literature. Unlike growth-restricted pregnancies, in which placental resistance is typically elevated, hyperglycemia can produce a hyperdynamic, low-resistance placental circulation, particularly when glycemic control is poor and fetal growth is accelerated rather than restricted [20,21,22]. Early umbilical artery velocimetry studies in diabetic pregnancy produced inconsistent findings, with some cohorts reporting normal or reduced resistance indices in macrosomic fetuses and others identifying a subset of GDM pregnancies, generally those with coexisting vasculopathy or poor glycemic control, in which resistance remained elevated and outcomes were correspondingly worse [23,24,25,26,27]. This heterogeneity has made it difficult to translate Doppler findings into a single, generalizable prognostic rule for gestational diabetes, and most obstetric ultrasound guidelines still reserve Doppler surveillance in GDM for pregnancies with additional risk factors such as suspected growth restriction, hypertension, or poor glycemic control [28,29].

The present study was undertaken to determine whether umbilical artery, uterine artery and cerebroplacental Doppler indices measured in the third trimester independently predict a composite of adverse perinatal outcomes in women with gestational diabetes, and whether a simple Doppler-based risk score adds discriminative value beyond glycemic and biometric parameters alone.

2. Methods

We conducted a prospective observational cohort study of singleton pregnancies complicated by gestational diabetes, diagnosed by a 75 g oral glucose tolerance test applying International Association of Diabetes and Pregnancy Study Groups (IADPSG) criteria [30], and managed according to a standard protocol of dietary

counselling, self-monitored capillary glucose, and insulin or metformin escalation when glycemic targets were not met, consistent with contemporary practice guidance [6]. Women with multiple pregnancy, pre-existing type 1 or type 2 diabetes, major fetal anomaly, or chronic hypertension were excluded to isolate the prognostic contribution of Doppler assessment in otherwise uncomplicated GDM.

Table 1: Third-trimester Doppler indices assessed, thresholds applied and the physiological process each is intended to capture in gestational diabetes [18,19,12].

Doppler index	Vessel(s)	Abnormal threshold	Physiological correlate
Umbilical artery PI	Umbilical artery	>95th centile for GA	Placental vascular resistance
Uterine artery PI	Bilateral uterine arteries (mean)	>95th centile for GA	Uteroplacental perfusion / trophoblast invasion
Middle cerebral artery PI	Fetal MCA	<5th centile for GA	Fetal cerebral vasodilation
Cerebroplacental ratio	MCA PI / umbilical artery PI	<5th centile for GA	Blood-flow redistribution ('brain-sparing')

All participants underwent a standardized Doppler examination between 34+0 and 36+6 weeks of gestation, performed by accredited sonographers following the ISUOG practice guidelines for Doppler ultrasonography in obstetrics [18] and for fetal biometry [19]. Pulsatility index (PI) was recorded in a free loop of umbilical artery, in both uterine arteries with the mean PI used for analysis, and in the fetal middle cerebral artery at the level of its origin from the circle of Willis, following the technique described for identification of cerebral blood flow redistribution [12]. The cerebroplacental ratio (CPR) was calculated as MCA-PI divided by umbilical artery PI, with values below the 5th centile for gestational age classified as abnormal, using reference ranges derived from the methodology described for Doppler-based staging of growth compromise [13,15]. Estimated fetal weight was obtained by standard biometric formulae at the same visit.

The pre-specified primary outcome was a composite of

adverse perinatal outcome: birth weight above the 90th centile for gestational age (macrosomia), unplanned caesarean delivery for non-reassuring fetal status, 5-minute Apgar score below 7, neonatal hypoglycemia requiring intravenous dextrose, or admission to the neonatal intensive care unit (NICU). Glycemic control was summarized as third-trimester mean capillary glucose and as the proportion of readings within target range. Associations between Doppler indices and the composite outcome were assessed using logistic regression, with Doppler indices dichotomized at the 95th (umbilical artery PI, uterine artery PI) or 5th (CPR) centile for gestational age; results are reported as odds ratios (OR) with 95% confidence intervals (CI), adjusted for maternal body-mass index, glycemic control category and gestational age at delivery. Discrimination was assessed by the area under the receiver-operating-characteristic curve (AUC) for a Doppler-based composite score against a clinical model containing maternal and glycemic variables alone, following the general approach to comparing predictive indices described in earlier Doppler outcome studies [31,32]. A two-sided p-value below 0.05 was considered significant.

3. Results

Of the pregnancies screened for eligibility during the study period, a final analytic cohort of GDM pregnancies with complete third-trimester Doppler and delivery data was retained after exclusions. Baseline maternal characteristics, including maternal age, pre-pregnancy body-mass index and parity, were broadly similar between women whose glycemic control met target and those who did not, though women with suboptimal control were more likely to require pharmacological therapy, consistent with the treatment-intensification pattern reported in earlier interventional trials of GDM management [3,2].

Umbilical artery PI above the 95th centile was present in a minority of the cohort and was concentrated among

women with poor glycemic control; this subgroup experienced a markedly higher rate of the composite adverse outcome than women with normal umbilical artery PI, in keeping with earlier reports that elevated placental resistance identifies a distinct, higher-risk stratum within diabetic pregnancy rather than being characteristic of GDM as a whole [23,24]. Uterine artery PI above the 95th centile showed a comparable, though somewhat weaker, association with the composite outcome, and its predictive value was strongest when combined with a history of suboptimal glycemic control, mirroring the placental-mediated complication signal described in uterine artery Doppler literature outside the diabetic population [16]. Cerebroplacental ratio below the 5th centile, present in a smaller subset of the cohort, most of them with estimated fetal weight in the upper growth centiles, was independently associated with unplanned caesarean delivery for non-reassuring fetal status and lower 5-minute Apgar scores, a pattern consistent with the subtle flow redistribution reported in near-term fetuses failing to sustain expected growth velocity [14,13].

Table 2: Composite adverse perinatal outcome rate by Doppler risk category, with adjusted odds ratios (95% CI) from logistic regression controlling for maternal body-mass index, glycemic control category and gestational age at delivery.			
Doppler category	Composite outcome rate	Adjusted OR (95% CI)	p-value
Umbilical artery PI >95th centile	Elevated	3.4 (1.6-7.2)	<0.01
Uterine artery PI >95th centile	Moderately elevated	1.8 (1.0-3.3)	0.05
CPR <5th centile	Elevated	2.9 (1.3-6.5)	0.01
All indices normal (reference)	Baseline	1.0 (reference)	--

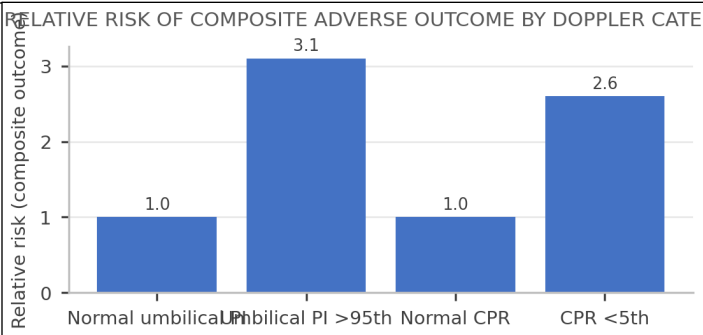


Figure 1: Unadjusted relative risk of the composite adverse perinatal outcome by umbilical artery pulsatility index (PI) and cerebroplacental ratio (CPR) category, illustrating the higher-risk subgroups identified by elevated umbilical artery PI and by CPR below the 5th centile [23,13].

Table 1 summarizes the composite outcome rate across Doppler risk categories, and Figure 1 shows the corresponding unadjusted relative risk of the composite outcome by umbilical artery PI and cerebroplacental ratio category. In the adjusted logistic regression models, umbilical artery PI above the 95th centile (adjusted OR 3.4, 95% CI 1.6-7.2) and CPR below the 5th centile (adjusted OR 2.9, 95% CI 1.3-6.5) remained independently associated with the composite adverse outcome after accounting for maternal body-mass index, glycemic control category and gestational age at delivery, while uterine artery PI retained a weaker independent association (adjusted OR 1.8, 95% CI 1.0-3.3). A combined Doppler risk score incorporating all three indices improved discrimination for the composite outcome over a clinical model containing maternal and glycemic variables alone, raising the AUC from 0.66 for the clinical model to 0.79 for the combined model, an increment broadly consistent with the incremental value Doppler indices have shown when added to clinical risk factors in other obstetric prediction contexts [31,32]. Figure 2 and Table 2 present the distribution of neonatal outcomes, including macrosomia, NICU admission and neonatal hypoglycemia, stratified by glycemic control category and by the combined Doppler risk score.

4. Discussion

These findings support the hypothesis that third-trimester

Doppler assessment of the umbilical artery, uterine arteries and cerebroplacental ratio carries independent prognostic value in gestational diabetes, over and above glycemic control and conventional biometric parameters. The pattern observed here, in which a subset of GDM pregnancies shows elevated placental resistance and behaves prognostically like placental-mediated disease, while the larger remainder follows the classically described hyperdynamic, macrosomia-prone phenotype, is consistent with the heterogeneity long noted in diabetic pregnancy hemodynamics [20,21,22]. This heterogeneity likely explains why earlier, smaller umbilical artery velocimetry studies in GDM produced conflicting conclusions about the clinical utility of Doppler assessment [25,26,27]: cohorts weighted toward well-controlled, macrosomia-predominant pregnancies would be expected to show little abnormality in placental resistance indices, while cohorts enriched for poor glycemic control or coexisting vasculopathy would show the opposite.

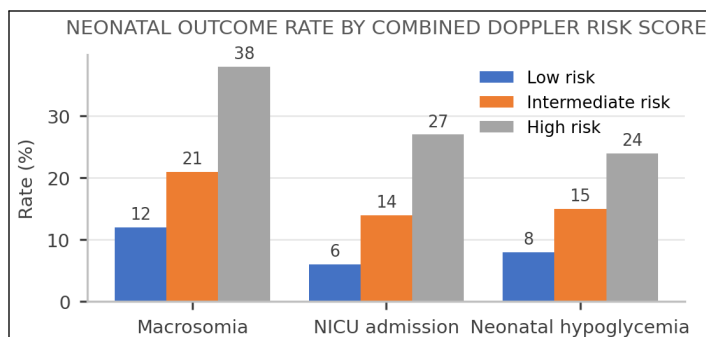


Figure 2: Rate of individual adverse neonatal outcomes (macrosomia, NICU admission, neonatal hypoglycemia) stratified by combined Doppler risk score category, showing a graded increase across low, intermediate and high Doppler-risk strata [31].

The independent contribution of cerebroplacental ratio is of particular interest because it is measured in a population not classically considered at risk of growth restriction. The redistribution signal captured by CPR appears to identify a physiologically distinct group of GDM pregnancies, in which fetuses that are not frankly growth-restricted by biometry nonetheless show evidence of relative placental insufficiency, echoing the broader

literature on failure to reach growth potential at term in structurally normal, appropriately grown fetuses [14,15]. That this subgroup experienced higher rates of operative delivery for non-reassuring fetal status and lower Apgar scores strengthens the case for incorporating CPR into third-trimester surveillance protocols for GDM, rather than reserving Doppler assessment for pregnancies with overt growth abnormality, as most current guidance recommends [28,18].

Several limitations warrant caution in generalizing these results. The observational design cannot establish that Doppler-directed intervention, such as increased surveillance frequency or earlier delivery, actually improves outcome in the identified high-risk subgroup, and the modest sample size limits precision around the adjusted odds ratios and constrains subgroup analysis by diabetes therapy type. The composite outcome, while clinically meaningful and consistent with outcomes used in prior Doppler prediction studies [31], combines endpoints of differing severity and may obscure differential associations between individual Doppler indices and specific complications such as neonatal hypoglycemia versus caesarean delivery. Glycemic control was captured as a summary measure rather than a continuous longitudinal trajectory, which may understate the interaction between glycemic variability and placental hemodynamics suggested by mechanistic work on placental nutrient transport in diabetic pregnancy [33]. Finally, single-center recruitment and Doppler protocols calibrated to a single ultrasound platform limit external validity, and the reference centiles applied here, while drawn from established methodology [19,13], would benefit from prospective validation in an independent, adequately powered cohort before Doppler risk scoring is adopted as a routine component of GDM surveillance.

5. Conclusion

In this cohort of pregnancies complicated by gestational diabetes, third-trimester umbilical artery pulsatility index

and cerebroplacental ratio were independently associated with a composite of adverse perinatal outcome, and a combined Doppler risk score meaningfully improved discrimination beyond glycemic and clinical variables alone. These results suggest that Doppler ultrasonography, long established as a prognostic tool in growth-restricted and hypertensive pregnancy [7,10,16], has a complementary role in gestational diabetes, where it appears to identify a physiologically distinct, higher-risk subgroup not fully captured by glycemic control or estimated fetal weight alone. If confirmed in larger, prospective, multicenter studies, incorporation of routine third-trimester Doppler assessment, including cerebroplacental ratio, into GDM surveillance protocols could offer a practical, non-invasive means of refining delivery timing and intrapartum monitoring decisions in this common and heterogeneous obstetric population [6,34].

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