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ORIGINAL ARTICLE

Second trimester abnormal uterine artery Dopplers and adverse obstetric and neonatal outcomes when PAPP-a is normal

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ABSTRACT

Objectives: To explore the association between abnormal uterine artery Dopplers (combined PI > 2.5) - with normal PAPP-A - and adverse obstetric/neonatal outcomes.

Methods: This was a retrospective cohort study of 800 patients between 1 March 2019 – 23 November 2021 in a tertiary UK hospital, where it is routine to measure uterine artery Dopplers of all pregnancies during their anomaly scans. 400 nulliparous women/birthing people with complete data were included. 400 nulliparous controls scanned in the same time frame (1.5 years) with normal PAPP-A and uterine artery Dopplers were matched for age and BMI. Outcomes included: mode of birth, postpartum complications, birth weight/centile, Apgar score, gestational age at delivery, neonatal unit admission, and clinical neonatal hypoglycemia. Multivariable analysis was used.

Results: Compared to controls, pregnancies with abnormal uterine artery Dopplers and normal PAPP-A were at increased risk of induction (46.5% vs 35.5%, $p = .042$), cesarean section (46.0% vs 38.0%, $p = .002$), emergency cesarean section (35.0% vs 26.5%, $p = .009$), and pre-eclampsia 5.8% vs 2.5%, $p = .021$). Their babies were more likely to be admitted to the neonatal unit – mostly for prematurity (15.3% vs 6.3%, $p = .0004$), hypoglycemia (4.0% vs 1.0%, $p = .007$), be small for gestational age (26.5% vs 11.5%, $p = .0001$), had intrauterine growth restriction (10.8% vs 1.3%, $p = .0001$), and be born prematurely (10.0% vs 3.5%, $p = .002$). Routine measurement of uterine artery Dopplers increased the detection rate of small for gestational age fetuses by 15.1%. Over half of the babies admitted with neonatal hypoglycemia in pregnancies with abnormal uterine artery Dopplers had an unexplained cause.

Conclusions: Pregnancies with abnormal uterine Dopplers are not only at increased risk of pre-eclampsia and small for gestational age fetuses/intrauterine growth restriction, but are also at increased risk of emergency cesarean section and adverse neonatal outcomes. The increased incidence of neonatal hypoglycemia is likely driven to some degree by prematurity and placental complications, but possibly also by undiagnosed glucose dysmetabolism. This may warrant routine measurement of uterine artery Dopplers in all pregnancies (regardless of risk), where feasible, to aid antenatal management and counseling.

CONTRIBUTION

What are the novel findings of this work?

Pregnancies with abnormal uterine artery Dopplers at the time of the anomaly scan and normal PAPP-A are at increased risk of having pre-eclampsia, small for gestational age fetuses, emergency cesarean, neonatal unit admission (including but not limited to prematurity), and neonatal hypoglycemia.

What are the clinical implications of this work?

Due to the significantly increased risk of adverse maternal and neonatal outcomes in first time mothers with increased uterine artery Dopplers despite normal PAPP-A, ultrasound assessment of placental function should be offered to all during their anomaly scans, subject to resources, to aid antenatal management and counseling. Further research is needed into undiagnosed diabetes.

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KEYWORDS

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Introduction

Uterine artery (UtA) Doppler indices as a predictive model for pre-eclampsia, small for gestational age (SGA) fetuses and fetal growth restriction (FGR) [1] have been explored since the 1980s [2]. These conditions have a significant impact upon maternal and fetal morbidity and mortality and their incidence is increasing as a result of increasing maternal age and maternal comorbidities, for example preexisting diabetes and hypertension [2]. The use of UtA Dopplers have also been incorporated into multiparameter prediction models which consider maternal demographics (age, BMI, ethnicity) as well as fetal biometry to evaluate the risk of stillbirth [3,4]. The National Institute for Health and Care Excellence (NICE) and the Fetal Anomaly Screening Programme (FASP) do not recommend universal UtA Doppler screening [5,6]. The Royal College of Obstetricians and Gynecologists (RCOG) state that UtA Dopplers should be performed between 20-24 weeks' gestation in those with three or more minor risk factors to identify fetuses at risk of SGA [1]. Since 2019 the UK Department of Health have launched an initiative to reduce stillbirth (Saving Babies' Lives version 2) which includes using UtA Doppler [7]. However universal UtA Doppler screening is not recommended in the UK or internationally (FIGO, ACOG, ISUOG] [8–10]. The association between abnormal UtA Dopplers, pre-eclampsia, and fetal growth restriction has been well documented [11].

In competing risks multiparameter models for prediction of preeclampsia both UtA Dopplers and placental associated plasma protein (PAPP-A) contribute to the overall risk assessment [12]. However there has been no study examining outcomes in those with high uterine resistance in the mid-second trimester yet normal PAPP-A levels.

In a small retrospective study there was an association with specific placental phenotypes and possible undiagnosed gestational diabetes (GDM); fetal vascular malperfusion (FVM) and undiagnosed glucose dysmetabolism [13]. Current incidence of GDM is approximately 10% but has been quoted higher depending on the classification criteria [14]. GDM has significant adverse outcomes including an increased lifetime risk of Type 2 diabetes, polyhydramnios, macrosomia, shoulder dystocia, neonatal hypoglycemia, stillbirth, birth trauma and intervention [15,16].

Assessment of UtA Dopplers was routinely performed at the anomaly scan at University College London Hospital (UCLH); and at the time of the study, not in the first trimester nuchal scan. The aim of this study was to examine the association between second trimester abnormal UtA Dopplers (in combination with a normal PAPP-A) and adverse obstetric and neonatal outcomes, with a particular focus on outcomes related to not just pre-eclampsia but also diabetes. The results of this study could yield information that will enable efficient use of a well-established and low-cost screening tool to aid improvement in obstetric and neonatal outcomes.

Materials and methods

This was a retrospective cohort study. Health Research Authority (HRA) and Health and Care Research Wales (HCRW) authority approval was gained (REC reference 22/HRA/1394). As data collected were anonymised and part of routine clinical care single patient consent was waived.

Participants were identified *via* search through the obstetric imaging database (Viewpoint^{TM} 5.0). Search parameters and inclusion criteria for the case group included: singleton pregnancy with a non-anomalous fetus, ultrasound dating, nulliparity, with sum of both UtA pulsatility index (PI) $\geq$2.5 [17] assessed during the routine fetal anomaly screening between 18 and 24 weeks of gestation between April 2019 and November 2021, first trimester PAPP-*A* $>$ .4 MoM, who delivered at UCLH. The sum of both UtA PI was used with $>$2.5 as an established cutoff value [17]. The starting timeframe was selected as all maternity patient records at UCLH became digitized shortly after April 2019, thus allowing efficient data retrieval. The end timeframe was selected as November 2021 as this allowed time for such patients to have reached at least 42 weeks' gestation. This search selected patients randomly who met the inclusion criteria in the specified timeframe. The search was repeated for the control group for the same inclusion criteria except for the combined uterine artery PI measured as normal ($<$2.5) at anomaly scan. Aspirin was not administered to patients based on raised uterine artery PI alone as this risk factor would have been identified at anomaly screening, at which the gestation would be too advanced for recommendation of aspirin [18–20]. The target sample size of 400 cases and 400 controls was pragmatic as there has been no prior evidence to inform power calculations. The control group were matched 1:1 for age and BMI (as per WHO classification) [21] as these are important confounders [22].

Anonymised patient information was exported into a Microsoft Excel spreadsheet. Records of each patient were searched by MJ and SJ using their hospital ID on the UCLH EPIC^{TM} patient record platform, and data

was retrieved. The outcomes assessed included antenatal variables (age, ethnicity, BMI, smoking status, medical comorbidities, combined UtA PI, glucose challenge test, glucose tolerance test, home blood glucose monitoring, diagnosis of GDM, liquor volume at last scan, antenatal conditions diagnosed, antenatal management), intrapartum variables (intrapartum complications, intrapartum CTG abnormalities, birth intervention), maternal variables (mode of delivery, postnatal complications) and neonatal variables (shoulder dystocia, APGARs, placental histology, neonatal unit (NNU)[this includes all levels withing the unit including neonatal intensive care] admission and indication, neonatal hypoglycemia <2mmol/l, birth weight, birth centile, gestational age at birth, small for gestational age (SGA), fetal growth restriction (FGR), stillbirth, umbilical cord abnormalities and neonatal problems diagnosed postnatally).

All pregnancies were screened for GDM. Those that did not meet the criteria for a glucose tolerance test would undergo a glucose challenge test. The glucose challenge test was performed in all pregnancies, with blood sampled at 1 h after 50 mg of glucose intake, and considered abnormal if serum glucose level was >7.7 mmol/L. Those with an abnormal glucose challenge test or who met the NICE criteria [23] then had a glucose tolerance test. The glucose tolerance test was performed with three samples at time 0 (fasting), 1 and 2 h after 75 mg of glucose intake and considered abnormal if serum glucose level was ≥5.3 mmol/L at time 0, ≥10.5 mmol/L (local consensus) at 1 h, or ≥8.6 mmol/L at 2 h.

Patients who had UtA combined PI >2.5 were followed up with growth scans at 28 and 36 weeks, with additional scans only at the discretion of the obstetrician responsible for their care. The UtA combined PI was not remeasured routinely in the third trimester.

Viewpoint utilized the Hadlock formula to generate estimated fetal weights [24]. FGR was defined as per the International Society of Ultrasound in Obstetrics and Gynecology Delphi consensus. Early FGR (<32 weeks) was defined as abdominal circumference (AC) <3rd centile or absent end-diastolic flow in the umbilical artery (UA) or a combination of abdominal circumference (AC)/estimated fetal weight (EFW) <10th centile with UtA PI > 95th centile, or UA PI >95th centile. Late FGR (≥32 weeks) was defined as AC/EFW <3rd centile or a combination of at least 2 of the following: AC/EFW <10th centile, AC/EFW dropping 2 quartiles on growth centiles, or cerebral-placental ratio <5th centile/UA PI >95th centile [25]. EFW, AC, UA, UtA centiles were based on these charts used for clinical purposes before (Management of late growth restriction: a pragmatic based approach, Peasley et al. personal communication).

Statistical analysis

The R^{TM} software for statistical analysis was used. Descriptive statistical analysis for each of the variables was performed.

We examined the prevalence of polycystic ovarian syndrome (PCOS), preexisting diabetes, hypertension, hypo and hyperthyroidism and thrombophillias in the two cohorts. Matching was used to reduce confounding and subsequently Chi-squared was used for univariable analyses. Having matched at baseline, we did not adjust for factors in the causative pathway and therefore logistic regression was not performed as it was not appropriate.

Results

400 cases and controls with full clinical outcome data were selected. The median age of participants was 33 years (range 18 to 49 years). Participants were mostly of white ethnicity, with little difference between the two groups. There was a marginally higher proportion of black ethnicity 42 *(10.5%)* vs 27 *(6.8%)* and a lower proportion of East Asian ethnicity 18 *(4.5%)* vs 34 *(8.5%)* in cases versus controls. There were low and similar cases of smokers 5 *(1.3%)* vs 2 *(.5%)* in cases versus controls.

There was near-identical prevalence of preexisting medical comorbidities in cases and controls: PCOS 25 (6.3%) vs 21 (5.2%), preexisting diabetes 0 (.0%) vs 2 (.5%), preexisting hypertension 4 (1.0%) vs 1 (.2%), hypothyroidism 25 (6.3%) vs 27 (67%), hyperthyroidism 2 (0.5%) vs 1 (0.2%) and any thrombophilia 15 (3.8%) vs 10 (2.5%) (Table 1).

There was no statistically significant difference in formal diagnosis of GDM between the two groups. The overall incidence of pre-eclampsia was low. There were 25 cases in the case group and 11 in the control group. The difference was statistically significant ($p = .02$). Of the 25 cases with diagnosis of pre-eclampsia in the case group, 15 *(60.0%)* were also SGA with 8 *(32.0%)* clinically diagnosed as FGR. Of the 10 cases in the control group, only 2 (20.0%) were also SGA and there were no cases of FGR (Table 2).

The detection rate by ultrasound of SGA overall (with or without pre-eclampsia) was 39.0% in the case group and 23.9% in the control group. In the case group, only 91 patients would have been identified as

requiring UtA Doppler according to the national guideline relevant to the maternity unit (RCOG 2014). By national UK criteria, only 25/107 cases of SGA in cases would have had third trimester ultrasound (26.8%).

There were the same number of pregnancies with obstetric cholestasis (6 vs 6) and reduced fetal movements (77 vs 77) in the case and control groups respectively. There was no statistical difference in incidence of prolonged rupture of membranes (PROM) in either groups (36 cases vs 39 controls, $p = .72$) or polyhydramnios (3 cases vs 4 controls, $p = .70$).

Table 1. Baseline findings.

Baseline findings	Cases *(%)*	Controls *(%)*
Ethnicity		
White	287 *(71.8)*	286 *(71.5)*
Black	42 *(10.5)*	27 (6.8)
East Asian	18 *(4.5)*	34 *(8.5)*
South Asian	44 *(11.0)*	44 *(11.0)*
White-Black	6 *(1.5)*	6 *(1.5)*
White-East Asian	2 *(0.5)*	2 *(0.5)*
White-South Asian	1 *(0.3)*	1 *(0.3)*
Smoking status		
Smoker	5 *(1.3)*	2 *(0.5)*
Medical comorbidities		
PCOS	25 *(6.3)*	21 *(5.3)*
Preexisting diabetes	0 *(0.0)*	2 *(0.5)*
Preexisting hypertension	4 *(1.0)*	1 *(0.3)*
Hypothyroidism	25 *(6.3)*	27 *(6.8)*
Hyperthyroidism	2 *(0.5)*	1 *(0.3)*
Thrombophilia	15 *(3.8)*	10 *(2.5)*

There were higher rates of induction in the case group vs the control group (42.5% vs 35.5%) which was statistically significant ($p = .04$) (Table 4). The commonest indications for induction in the case group were reduced fetal movements (27.6%), SGA (15.3%), PROM (11.8%), GDM (8.8%) and pre-eclampsia (7.1%). Reduced fetal movements was the commonest indication for induction in the control group (21.8%), followed by PROM (19.0%), post-dates (16.2%), GDM (14.8%), high maternal age (5.6%) and SGA (5.6%) (Table 5) (Figure 1). SGA as reason for induction was more prevalent in the case group (26 cases vs 8 controls, $p = .01$).

Pregnancies in the case group were more likely to have an emergency cesarean section (CS) compared to controls (35.0 vs 26.5%, $p = 0.009$) and less likely to require an instrumental delivery than controls (21.5 vs 29.0%, p value 0.015) (Table 3). The indications for an emergency cesarean were cardio-toco-graphy (CTG) concerns (67.6%), failure to progress (31.0%), fetal or maternal concerns (e.g. FGR, pre-eclampsia (5.0%), malpresentation (6.0%) and maternal request (1.0%) (Table 4). In comparison to the control group, pregnancies in the case group were more likely to undergo an emergency CS due to CTG concerns (67.9 vs 41.5%, $p = .0003$) but less likely due to failure to progress (22.1 vs 44.3%, $p = .0002$) and maternal request (0.7 vs 5.7%, $p = .02$) than the controls (Table 6). There were no significant differences in the incidence of abnormal

Table 2. Antenatal events.

Antenatal events	Study group *n (%)*	Control group *n (%)*	*p* value	OR	CI (95%)	PPV *(%)*
GDM	53 *(13.3)*	50 *(12.5)*	.75	1.07	0.71 to 1.62	–
Reduced fetal movement	77 *(19.3)*	77 *(19.3)*	1.00	1.00	0.70 to 1.42	–
Pre-eclampsia	25 *(6.3)*	11 *(2.8)*	**.02**	2.36	1.14 to 4.86	6.25
Polyhydramnios	3 *(0.8)*	4 *(1.0)*	.70	0.75	0.16 to 3.36	–

Table 3. Neonatal outcomes.

Neonatal outcome	Study group *n (%)*	Control group *n (%)*	*p* value	OR	CI (95%)	PPV (%)
Neonatal unit admission	61 *(15.3)*	25 *(6.3)*	**<.001**	2.70	1.66 to 4.40	15.25
Neonatal hypoglycemia (<2.0 mmol/l)	17 *(4.3)*	4 *(1.0*	**.006**	4.39	1.47 to 13.18	4.25
SGA	106 *(26.5)*	46 *(11.5)*	**<.001**	2.77	1.90 to 4.05	26.50
FGR	43 *(10.8)*	5 *(1.3)*	**<.001**	9.51	3.73 to 24.29	10.75
Preterm	40 *(10.0)*	14 *(3.5)*	**.002**	3.06	1.64 to 5.73	10.00
Shoulder dystocia	5 *(1.3)*	8 *(2.0)*	.40	0.62	0.20 to 1.91	–

Table 4. Intrapartum/postnatal outcomes.

Intrapartum & postnatal outcome	Study group n *(%)*	Control group n *(%)*	*p* value	OR	CI (95%)	PPV (%)
Induction	170 *(42.5)*	142 *(35.5)*	**.04**	1.34	1.01 to 1.79	42.50
Abnormal CTG	169 *(42.3)*	151 *(37.8)*	.19	1.21	0.91 to 1.60	–
Cesarean section	184 *(46.0)*	152 *(38.0)*	**.02**	1.39	1.05 to 1.84	46.00
Emergency cesarean	140 *(35.0)*	106 *(26.5)*	**.01**	1.49	1.10 to 2.02	35.00
Forceps	49 *(12.3)*	66 *(16.5)*	.87	0.71	0.47 to 1.05	–
Ventouse	37 *(9.3)*	50 *(12.3)*	.17	0.71	0.46 to 1.12	–
Total instrumental	86 *(21.5)*	116 *(29.0)*	**.01**	0.67	0.49 to 0.93	21.5
Spontaneous vaginal delivery	130 *(32.5)*	132 *(33.0)*	.88	0.98	0.73 to 1.31	–
PPH	209 *(52.3)*	230 *(57.5)*	.14	0.81	0.61 to 1.07	–
$3^{rd}/4^{th}$ degree tear	9 *(2.3)*	5 *(1.3)*	.28	1.82	0.60 to 5.47	–

Table 5. Induction indications.

Induction indication	Study group *n* (%)	Control group *n* (%)	*p* value	OR	CI (95%)
Reduced fetal movement	47 (27.6)	31 (21.8)	.24	1.37	0.81 to 2.30
Prolonged rupture of membranes	20 (11.8)	29 (20.4)	**.04**	0.52	0.28 to 0.97
Post-dates	13 (7.6)	23 (16.2)	**.02**	0.43	0.21 to 0.88
GDM	15 (8.8)	21 (14.8)	.10	0.56	0.28 to 1.13
SGA	26 (15.3)	8 (5.6)	**.01**	3.02	1.32 to 6.91
High maternal age	6 (3.5)	8 (5.6)	.37	0.61	0.21 to 1.81
Pre-eclampsia	12 (7.1)	5 (3.5)	.17	2.08	0.72 to 6.06
Pregnancy induced hypertension	6 (3.5)	3 (2.1)	.46	1.70	0.41 to 6.90
Obstetric cholestasis	4 (2.8)	4 (2.8)	.80	0.83	0.20 to 3.39
FGR	4 (2.4)	4 (2.8)	.80	0.83	0.20 to 3.39
Maternal medical co-morbidities	3 (1.8)	2 (1.4)	.80	1.26	0.21 to 7.63
Oligo/polyhydramnios	1 (0.6)	1 (0.7)	.90	0.83	0.05 to 13.5
Maternal request	2 (1.2)	1 (0.7)	.67	1.67	0.15 to 18.7
Antepartum hemorrhage	2 (1.2)	1 (0.7)	.67	1.67	0.15 to 18.7
Polymorphic eruption of pregnancy	0 (0.0)	1 (0.7)	–	–	–
Venous thromboembolism risk	1 (0.6)	0 (0.0)	–	–	–
Intrauterine death	3 (1.8)	0 (0.0)	–	–	–
Long latent phase	1 (0.6)	0 (0.0)	–	–	–
Meconium	2 (1.2)	0 (0.0)	–	–	–
Raised UtA PI	1 (0.6)	0 (0.0)	–	–	–
Abnormal fetal Dopplers	1 (0.6)	0 (0.0)	–	–	–

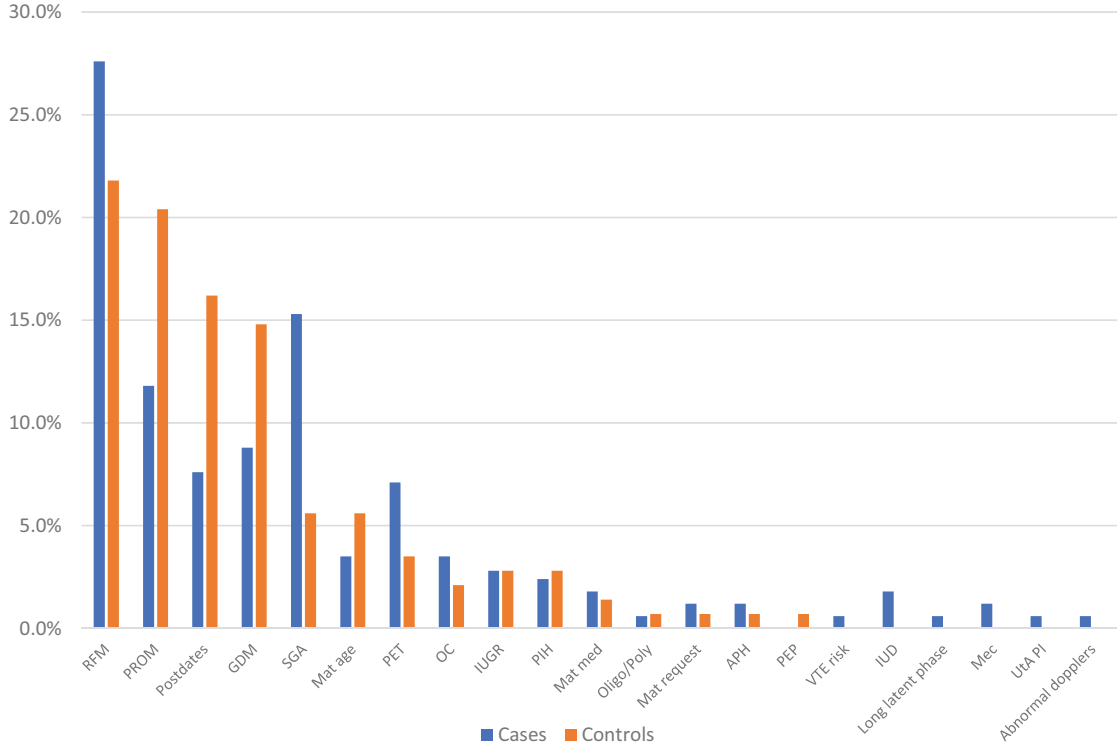

Figure 1. Indications for induction.

CTG, spontaneous vaginal delivery or maternal postpartum complications between the two groups.

Neonatal complications

Compared to controls, pregnancies with increased UtA Dopplers were more likely to be born preterm, require neonatal unit admission, be SGA/diagnosed with FGR, and have neonatal hypoglycemia (Table 3). Of the cases with hypoglycemia, 23.5% were secondary to presumed sepsis, 11.8% secondary to poor feeding and prematurity, 5.9% were due to diagnosed GDM, and 47.1% were of unknown cause. When limited to babies born at term, the difference between cases and controls remained statistically significant ($p = .01$).

The commonest reasons for NNU admission were prematurity (37.7%), respiratory distress syndrome (24.6%) and suspected sepsis (19.7%). 50.8% of NNU admissions had an emergency CS, of which 32.7% had an induction of labor. 39.3% of babies who went to

Table 6. Emergency CS indications.

EMCS indication	Study group *n (%)*	Control group *n (%)*	*p* value	OR	CI (95%)
CTG concerns	95 *(67.9)*	44 *(41.5)*	**.00**	2.97	1.76 to 5.03
Failure to progress	31 *(22.1)*	47 *(44.3)*	**.00**	0.36	0.21 to 0.62
Fetal/maternal concerns e.g. SGA, PET	7 *(5.0)*	6 *(5.7)*	.82	0.88	0.29 to 2.69
Malpresentation in labor	6 *(4.3)*	3 *(2.8)*	.55	1.54	0.38 to 6.29
Maternal request	1 *(0.7)*	6 *(5.7)*	**.02**	0.12	0.01 to 1.01

NNU were SGA, 23.0% were thought to be FGR and 14.8% were born to mothers who had developed pre-eclampsia.

Of the babies who were admitted to NNU – 78.7% would have been considered low risk antenatally for screening for SGA according to GTG criteria alone.

Discussion

The results suggest that pregnancies who have raised UtA PI in the context of normal PAPP-A are more likely to have pre-eclampsia, SGA, FGR, induction as a result of higher SGA pick-up, emergency cesarean, NNU admission and neonatal hypoglycemia. The increased risk of NNU admission is not caused by prematurity alone. Furthermore, the odds of neonatal hypoglycemia are increased, possibly through a high incidence of prematurity and placental complications, but also further undiagnosed factors.

This was a single center study, but the maternity unit (UCLH) covers a large geographical area with over 6000 deliveries per year and a diverse population. Although this was a retrospective cohort observational study, cases and controls were matched on two important confounders (age and BMI), There was also a very similar incidence of baseline characteristics between the two groups so these possible confounding factors have already been corrected. All women were nulliparous, with no preexisting risk factors related to obstetric history. We were able to analyze a large sample size and a complete data set. The external validity is also reasonable; the patients were selected randomly as long as they met the inclusion criteria during the selected timeframe.

The most recent systematic review examining the prognostic value of second trimester UtA Doppler alone was over a decade ago, and a Cochrane review which concluded there were no differences in perinatal and maternal outcomes in those with abnormal UtA PI [26]. The Cochrane review was only able to examine two randomized control trials (RCT), neither of which accounted for the presence of normal PAPP-A and did not examine all possible adverse neonatal outcomes including neonatal hypoglycemia. Conversely, a systematic review with bi-variate meta-analysis by Cnossen [27] two years prior examined the predictive value of UtA for pre-eclampsia and FGR and concluded that abnormal UtA is a good predictor of pre-eclampsia. Our results echo the review by Cnossen et al. with significant increases in the incidence of pre-eclampsia, but also SGA, FGR, emergency CS, NNU admission and neonatal hypoglycemia. It also affirms results seen in Familiari et al. in which there was increased pick-up of SGA [3,4]. Importantly, 78.7% of our study group would have otherwise been considered low risk as per current national guidelines [1,5–10] yet were at high risk of adverse outcomes.

The results of this study support the case for performing uterine artery Dopplers on all nulliparous singleton pregnancies in the second trimester, on the basis of effectiveness alone. We have not examined feasibility and cost-effectiveness, however. The translation to clinical practice may prove to be challenging, considering ongoing national shortages of obstetrically-trained sonographers, for example in the UK [28]. The false-positive rate (10%) and its impact on medicalising pregnancies also needs to be taken into consideration [29]. It might be that initially it is limited to centers of excellence, but this poses then concerns with regards to equity of access.

The findings suggest that beyond pre-eclampsia, prematurity and/or small fetal size there might be additional factors responsible for neonatal hypoglycemia in pregnancies with high resistance in uterine arteries but normal PAPP-A. A possible cause could be underlying glucose dysmetabolism as certain placental pathologies, such as FVM, have been shown to be associated with these characteristics; normal PAPP-A, high combined UtA PI, and signs of possible undiagnosed diabetes [13]. At present, this is hard to discern due to the limitations of current diagnostic criteria for gestational diabetes.

In conclusion, uterine artery Doppler studies are clearly a useful and informative tool in the identification of pregnancies at risk of adverse obstetric and neonatal outcomes, including neonatal hypoglycemia. More research is needed to further investigate the association of high resistance at the time of anomaly scan with glucose dysmetabolism and associated complications.

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Disclosure statement

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Data availability statement

The data that support the findings of this study are available from the corresponding author, [DS], upon reasonable request.

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