Comparison of color Doppler uterine artery indices in a population at high risk for adverse outcome at 24 weeks' gestation

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ABSTRACT

Objective *To compare uterine artery Doppler velocity and impedance indices in the presence and absence of uterine artery waveform notches, in the prediction of adverse pregnancy outcome in high-risk women.*

Methods *One hundred and fifty-seven women identified at Doppler screening as being at 'high risk' underwent a further uterine artery Doppler assessment at 24 weeks' gestation. Pulsatility and resistance indices and minimum, time averaged and time averaged maximum velocities were measured, and the presence of bilateral notches noted. Adverse outcomes were pre-eclampsia, birth weight less than the tenth centile, placental abruption and intrauterine death. The best cut-off for each parameter was assessed by univariate logistic regression, and the comparative performance of the screening parameters was assessed using kappa values.*

Results *The best performing index in the presence of bilateral notches was mean resistance index, for a cut-off of 0.67, giving a kappa value of 0.65. Mean pulsatility index and lowest pulsatility index performed similarly well, both with kappa values of 0.58. All velocity indices apart from lowest minimum velocity had kappa values of < 0.4. When indices were analyzed, irrespective of notch status, mean resistance and mean pulsatility indices performed similarly, with kappa values of 0.49 and 0.46, respectively; mean minimum velocity had a kappa value of 0.4.*

Conclusions *In a high-risk population, uterine artery Doppler mean resistance indices perform better than do velocity indices in the prediction of adverse pregnancy outcome, irrespective of notch status. Copyright © 2003 ISUOG. Published by John Wiley & Sons, Ltd.*

INTRODUCTION

Abnormal uterine artery Doppler in the second trimester of pregnancy is known to predict adverse outcomes related to pre-eclampsia, intrauterine growth restriction, placental abruption and intrauterine death. The clinical application of uterine artery Doppler has, however, been hampered by the widely differing methodologies employed in screening studies. There is little consensus as to the ideal gestational age at screening, the equipment used or whether the presence of uterine artery notches or a more objective measure such as impedance or velocity indices should be used. Studies using impedance indices have relied upon using 90th or 95th centile cut-offs for the resistance index (RI) and the pulsatility index (PI)[1,2]. The most frequent descriptors of the uterine artery waveform are the measurement of impedance and velocity indices and the presence of uterine artery notches. Authors have variously described uterine artery Doppler on the basis of an arithmetic mean of the values of the uterine artery parameters for both sides, 'best side' or 'worst side' uterine arteries[3].

This study describes a comparison of uterine artery impedance and velocity parameters in determining the risk of a composite adverse outcome referring to pre-eclampsia, delivering a small-for-gestational age baby, placental abruption and intrauterine death for a high-risk, mixed parity population of women at 24 weeks' gestation attending an inner city teaching hospital. Uterine artery indices are considered in the presence of bilateral uterine artery notches, and independent of notch status.

METHODS

All women attending for an anomaly scan at 23 weeks' gestation with a singleton pregnancy also underwent

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transabdominal color Doppler uterine artery screening in the antenatal ultrasound department of an inner city university teaching hospital. Women with increased uterine artery impedance (mean PI > 1.45) or bilateral uterine artery notches underwent follow-up assessment from 24 weeks by one of four of the authors (G.A., H.M.-.L., M.P. or C.L.) using an Acuson Aspen (Acuson Co., Mountain View, CA, USA) color Doppler ultrasound machine with a 3-MHz curvilinear probe. The machine software allowed direct calculation of all the impedance and velocity parameters mentioned in this study.

Data from 157 women with singleton pregnancy and no obvious fetal abnormality collected consecutively over a 6-month period were analyzed prospectively. The results of the uterine artery Doppler (PI, presence of early diastolic notches) were available to clinicians in accordance with the normal practice at this center.

Both uterine arteries were insonated. The uterine artery was identified in all cases with color Doppler at the point of its apparent crossing over the external iliac artery. The pulse Doppler gate was placed over the uterine artery with an angle of insonation $< 60°$, and when at least three similar consecutive waveforms were obtained, one waveform was taken for the measurement of parameters. Angle correction using the ultrasound machine's software was carried out prior to measurement of indices in all cases. RI, PI, time averaged velocity (TAV), time averaged maximum velocity (TAMXV) and minimum velocity (Vmin) were measured and the presence of early diastolic uterine artery notches was noted. All uterine artery waveforms were captured as thermal images identified by name and identification number and stored with a printed computer record of the patient's scan (Fetal Database, The Fetal Medicine Foundation, London, UK). Interobserver and intraobserver variabilities for Doppler resistance and velocity indices from our unit have been detailed in previous studies[2,4].

Adverse outcome was defined as the occurrence in a woman of one or more of the following: pre-eclampsia, birth weight $< 10^{th}$ centile for sex and gestation[5], placental abruption or intrauterine death. Pre-eclampsia was defined as blood pressure > 140/90 mmHg with ≥ 300 mg/24 h urinary protein. If a urinary protein collection was not performed, then urine dipstick testing of > 300 mg/L protein was considered as evidence of proteinuria. Placental abruption was defined as vaginal bleeding and evidence of fetal compromise leading to emergency delivery at which there was evidence of retroplacental clot.

The best cut-off for each parameter PI, RI, TAV, Vmin and TAMXV was calculated in each woman for the highest and lowest value of the two uterine arteries, and for the mean of both right and left sides. The best cut-off was determined by univariate logistic regression for all women irrespective of notch status ($n = 157$) and for those with bilateral notches ($n = 40$). The corresponding kappa value was calculated at the best cut-off level of each parameter. Analyses were performed using Statistical Program for Social Sciences (SPSS) version 8 (SPSS, Chicago, IL, USA).

RESULTS

Data from 157 women scanned at a median of 24 (range, 23–26) weeks, were analyzed. There were no missing outcomes. Of 157 women, 40% were primigravid and 16.5% were smokers; 43.9% were Afro-Caribbean, 45.2% were Caucasian and 10.8% were of other ethnicity. There were 50 women with adverse outcomes in this group: 20 cases of pre-eclampsia, 34 of birth weight $< 10^{th}$ centile, three cases of intrauterine death and five of placental abruption.

Table 1 shows the comparison between uterine artery indices for those women with bilateral notches only. Table 2 includes all women irrespective of notch status. Kappa values < 0.4 suggest poor or fair agreement, 0.4–0.6 suggests moderate agreement, 0.6–0.8 suggests good agreement and > 0.8 suggests excellent agreement. Accordingly, the results for which kappa values were < 0.4 are not shown. Sensitivity, specificity and positive and negative predictive values refer to any of the adverse outcomes detailed above.

Table 1 Screening results for women with bilateral notches ($n = 40$)

Parameter	Best cut-off	Kappa	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
Mean RI	0.67	0.65	90.5	73.3	82.6	84.6
Lowest PI	1.15	0.58	83.3	75	83.3	75
Mean PI	1.41	0.58	88	68.8	80.8	78.6
Lowest RI	0.62	0.54	80.1	73.3	80.1	73.3
Highest PI	1.62	0.52	87.5	62.5	77.8	76.9
Highest RI	0.71	0.47	85.7	60	75	75
Lowest Vmin (m/s)	0.27	0.42	80	62	76	67

Indices are shown in descending order of kappa value. (Kappa values ≤ 0.4 not shown.) RI, resistance index; PI, pulsatility index; Vmin, minimum velocity.

Table 2 Screening results for women independent of notch status (*n* = 157)

Parameter	Best cut-off	Kappa	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
Mean RI	0.69	0.49	56.5	89.6	72.2	81.1
Mean PI	1.51	0.46	52	90.7	72.2	80.2
Mean Vmin (m/s)	0.29	0.40	50	87.8	64.7	79.6

Indices are shown in descending order of kappa value. (Kappa values ≤ 0.4 not shown.) RI, resistance index; PI, pulsatility index; Vmin, minimum velocity.

DISCUSSION

This study compares absolute velocities with indices of resistance, with and without bilateral notches, in predicting adverse outcome for women already found to be 'high risk' undergoing further uterine artery Doppler assessment at 24 weeks' gestation. The best screening performance in this population, irrespective of notch status, was achieved using mean PI or mean RI.

This was, however, a selected high-risk population, not representative of an unselected screened population. These women therefore had a correspondingly higher (approximately one third) incidence of adverse outcome. The population selection is, however, unlikely to have affected the relative performance of the indices compared to one another, although the data are not appropriate to generate centile cut-offs for impedance and velocity parameters in a general population. Similarly, the sensitivities, specificities and positive and negative predictive values given are for comparative purposes only within this study and cannot be applied to a general population.

In the presence of bilateral uterine artery notches, mean PI > 1.41 or mean RI > 0.67 had sensitivities for the prediction of adverse outcome in the region of 90%, with positive predictive values of over 80%. When considered independently of notch status, kappa values and sensitivity, specificity and positive and negative predictive values were still fair with a mean RI > 0.69, or mean PI > 1.51, giving sensitivities for adverse outcome of over 50% with positive predictive values of over 70%.

The velocity indices TAV, TAMXV and Vmin all performed poorly compared with PI and RI. The best performing velocity index was worst-side (lowest) Vmin < 0.27 m/s in the presence of bilateral notches, with a kappa value of 0.42, sensitivity of 80% and positive predictive value of 76%. All indices, be they of resistance or velocity, were best at predicting adverse outcome if combined with bilateral notches. A recent study[6] compared RI and systolic/end-diastolic ratios in relation to notches and the placental site. They concluded that the association between uterine notches and RI increases the sensitivity for adverse outcome at a fixed 'false-positive' level of 17%, but with a fixed false-positive rate of 11%, the presence of notches did not increase the sensitivity. The placental site did not play a significant role in determining on which side a parameter should be measured.

The problem with uterine artery screening studies has been the need for a subjective interpretation of whether an early diastolic notch is present in the uterine artery waveform. This has led to several studies attempting to quantify a notch, for example by using the peak systolic over protodiastolic ratio[7], calculating the notch index[8] or an automated computer analysis of the early diastolic notch[9]. None provides an entirely satisfactory method that can easily be applied in the obstetric ultrasound setting. A recent study of uterine artery Doppler screening in over one thousand primigravid women, however, showed good agreement between operators for the presence of bilateral notches, with a kappa value of 0.66[10].

Chan *et al.*[11] used continuous wave Doppler in 358 medium-risk women, performing RI measurements and noting the presence of bilateral notches at 20, 28 and 36 weeks. This study showed that, in medium-risk women, the best criteria were the combination of mean RI > 90th centile with bilateral uterine artery notches at 20 weeks. This gave a relatively poor kappa value of 0.3, for a positive predictive value of 93% for any complication. Zimmermann *et al.*[12], in a study of 175 high-risk women, showed that either bilateral uterine artery notches or mean RI > 0.68 performed similarly well in screening for pre-eclampsia or growth restriction at 21–24 weeks, but concluded that a combination of the two was the most effective.

We have established in this comparison of velocity and impedance indices irrespective of notch status in a high-risk population, that the best performance is given by mean PI and mean RI. This finding adds additional weight to the discussion on the use of quantitative as opposed to subjective assessment of the uterine artery waveforms in a screened population[13]. Furthermore, quantitative uterine artery indices allow individualized risk assessment for adverse maternal outcome related to impaired placentation[14]. This removes the operator-dependent assessment of a notch, and allows an objective method of calculating a woman's individual level of risk for adverse outcome.

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