New score by color Doppler ultrasound indicating placental vascular resistance and pregnancy outcome in high-risk pregnancy

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Received 20 April 2011; accepted 26 April 2011
Available online 5 July 2011

KEYWORDS
Color Doppler;
Placental vascular resistance;
Pregnancy;
Uterine artery

Abstract  Aim of the work: To evaluate the role of the new placental score (PLS) by combining the Doppler umbilical artery score (blood flow classes, BFC) and the uterine artery score (UAS) to predict the pregnancy outcome in high risk pregnancy.

Patients and methods: Forty pregnant ladies with high risk pregnancy were included in the study. The UAS and the BFC were combined to form a placental score (PLS) as an expression of general placental vascular resistance PLS = BFC + UAS, with figures in the range 0–7. Serial examinations were performed for each patient, in the 3d trimester. The results of last examination were related to the three perinatal outcome variables; premature birth, small for gestational age (SGA), and delivery by cesarean section (CS).
1. Introduction and rationale

Characteristic physiological changes develop in placental bed vessels during normal pregnancy. In early pregnancy, placental trophoblast cells invade the underlying spiral and radial arteries and transform the vessel wall structure with smooth muscle cells to become large flaccid dilated channels without contractile properties. These physiological changes are the basis for the development and increase in uterine artery blood flow during normal pregnancy; from 50 ml/min in early pregnancy to 700 ml/min at term. The conversion of sub-placental vessels is partly or totally absent in pregnancies complicated by IUGR or pre-eclampsia (1).

An increased utero-placental vascular resistance is a significant finding associated with complications like preterm delivery, small-for-gestational age (SGA) newborns, and operative delivery (2,3).

In 1983, Campbell and co-worker first presented data on utero-placental blood flow. They studied the arcuate arteries. A “notch” in early diastole was then first described as a marker of increased utero-placental vascular resistance. A single arcuate artery might represent only 10% of placental circulation, so recent research has therefore focused on blood flow in the main uterine arteries (4).

Uterine artery Doppler seems to give comparable information to those of the umbilical artery, but it can be difficult to interpret as there are two arteries, which might show notching and/or increased pulsatility index (PI) as signs of increased vascular impedance (5). Combining the information on vascular resistance on both sides in a new score might simplify and improve evaluation of placental circulation. The uterine artery score possesses a high predictive value regarding adverse perinatal outcome (6).

The umbilical circulation seems continually evolving but the utero-placental circulation becomes relatively fixed by the 26th week of pregnancy. Intra-and interobserver variations in many studies of the Doppler assessment of umbilical arterial flow velocity were around 10–14% and 5–9%, respectively (7,8). Besides the different errors of different location of Doppler samples from the fetal ends of the umbilical cord and those from the placental end (9). Also, in a group of pre-eclamptic patients in a study done by Gudnason et al. (2005), they found that signs of increased vascular impedance were much more frequent in the uterine than in the umbilical arteries and were strongly related to adverse outcome of pregnancy (10).

Gudmondsson et al. (2003) created a new scoring system by combining the Doppler results of umbilical artery score and the uterine artery score to predict the pregnancy outcome (2). This work was conducted to evaluate this new placental score in prediction of outcome in high risk pregnancy.

2. Patients and methods

Uterine and umbilical artery Doppler velocimetry was evaluated in high risk pregnancies. The umbilical artery flow spectrum was semi quantitatively divided into four blood flow classes (BFC), expressing signs of increasing vascular resistance. The uterine artery Doppler flow spectrum was divided into five uterine artery scores (UAS) taking into account presence/absence of notching and/or increase in PI. By adding UAS to BFC, a new placental score (PLS) was constructed with values ranging from 0 to 7, indicating general placental vascular resistance. The scores, then were related to three outcome variables; small-for gestational age (SGA), premature delivery (<37 weeks), and cesarean section (11).

Forty patients (18–45 years) who presented to the OB outpatient clinic and Radiology department in the Suez Canal University Hospital for routine antenatal care were included in the study, over a period of one year (January 2005–January 2006).

2.1. Inclusion criteria

(1) Singleton pregnancy.
(2) Third trimester of current pregnancy.
(3) High risk pregnancy includes:
   (a) Pregnancy-induced hypertension (PIH), defined as a systolic and/or diastolic blood pressure increased by at least 30 and 15 mmHg, respectively, after 20 weeks of gestation.
   (b) Pre-eclampsia (blood pressure of 140/90 mmHg and proteinuria (>0.3 g/1 urine).
   (c) Suspected intra-uterine growth restriction, IUGR (fetal weight >2 SD below the expected mean of the reference population).
   (d) Vaginal bleeding (ante-partum hemorrhage).
   (e) Oligohydramnios (amniotic fluid index < 50 mm).
   (f) Post-term pregnancy (>42 weeks).
   (g) Diabetes mellitus.
   (h) Decreased fetal movements.
   (i) Previous history of perinatal death, IUGR or PIH.

2.2. Exclusion criteria

(1) Multiple pregnancy (more than single fetus) because of high incidence of complicated-pregnancy and difficulty of uterine artery study.
(2) Fetal congenital anomalies by ultrasound.
2.3. Ultrasound examination

Ultrasound examination was performed with an Acuson 125xp-10 using 3.5 MHz sector transducer, pulsed waved Doppler with color Doppler options used. Modes used are M mode for heart rate, B mode for real time ultrasound examination and PW mode for Doppler flow velocity wave form study.

Follow up scan was done until delivery but cases with abnormal Doppler study in previous examination were examined every week. Only the results of the last Doppler examination performed within 7 days of delivery were considered in the subsequent correlation with perinatal outcomes.

The patients were examined in semi-recumbent position. Firstly the uterine contents were scanned with real time ultrasound (B mode) in order to certain the biophysical profile.

2.4. Doppler study

By using Doppler flow velocity waveform study, uterine and umbilical arteries were examined.

The umbilical artery blood velocity signals were obtained from free-floating central waveforms and were analyzed for S/D ratio. The spectrum of maximum blood velocity in the umbilical artery is divided into four semi quantitatively blood flow classes (BFC) based on the waveform pattern, as modified after.

Blood flow classes (11):

0-Normal S/D ratio < 3 (Fig. 1).
I-High S/D ratio > 3, but normal forward blood flow during diastole (Fig. 2).
II-Absent end diastolic blood flow.
III-Reversed blood flow in diastole.

Both uterine arteries were localized by color flow mapping in an oblique scan and blood flow velocity was recorded in the artery just cranial to the crossing of the uterine artery.

Uterine artery vascular impedance Doppler velocimetry is defined as increased if the PI was > 1 after 24 weeks of gestation, according to Hofstaetter et al. (1996) (12).

The uterine artery blood flow velocity waveforms were divided into five uterine artery scores (UAS) depending on the presence of an increased PI and or presence of an early diastolic notch according to Sekizuka et al. (1997) (13).

Both uterine arteries were examined for the presence or absence of a systolic or diastolic notch (at least one side of the uterus). A systolic notch was defined as a momentary decrease in the rate of decline in the maximal flow velocity during the decelerative phase of the systolic wave.

A diastolic notch was defined as a decrease in the maximal flow velocity below the maximum diastolic velocities, occurring just after the systolic wave (14).

Uterine artery score:

0-Normal blood velocity waveforms in both arteries (Fig. 3).
I-One abnormal parameter presents (high PI or notch) (Fig. 4).
II-Two abnormal parameters.
III-Three abnormal parameters.
IV-Four abnormal parameters present (i.e., high PI and notching in both arteries).

The UAS and the BFC were combined to form a placental score (PLS) as an expression of general placental vascular resistance PLS = BFC + UAS, with figures in the range 0–7.

Serial examinations were performed for each patient, the first with the start of the third trimester (28th week) and the second was carried out at 35 weeks and the last examination was about one week before delivery. The results of last examination were related to the three perinatal outcome variables; premature birth, small for gestational age, and delivery by cesarean section.

Receiver operating characteristic curve (ROC) was used for data analysis. Chi-square was done for quantitative values and P-value was considered significant if \( P < 0.05 \).

This study was done according to the world health research ethical considerations.

3. Results

The study included 40 patients (57.5%) aged between 18 and 35 years old, while (42.5%) were above 35 years. The majority (77.5%) were multipara.

The 1st group of studied patients was hypertensive with pregnancy, with a progressive course in (70%) regressive in (20%) and stationary in (10%) of patients. The majority
(90%) developed pre-eclampsia/eclampsia syndrome during pregnancy. The 2nd group included 10 diabetic ladies. Half of them developed diabetes during pregnancy.
The 3rd group developed (IUGR).
The 4th group of patients was subdivided into four sub-
groups of vaginal bleeding (3 patients) post date pregnancy
(3 patients), oligohydramnios (2 patients) and absent or
decreased fetal movements (2 patients).

The scores of the umbilical as well as the uterine artery were
evaluated among all patients. The majority (75% and 70%)
had score 0 for both umbilical and uterine arteries, respec-
tively. Twenty-five percentage had score 1 for both arteries,
while only 5% had score II for uterine artery. None of the pa-
tients had any higher scores for both arteries (Table 1).

The relation between umbilical artery score and pregnancy
outcome was evaluated in the study population (Table 2,
Graph I). We found that the group of the zero score was liable
to CS delivery (50%), babies small for age, SGA (20%) and
combined CS and SGA in 23%.

– Score (I) group was liable for CS (20%), CS and preterm
delivery (40%) and preterm delivery and SGA (40%).
\( P < 0.05 \).

The relation between uterine artery score and pregnancy
outcome was evaluated (Table 3, Graph II) and revealed the
followings:

– Score (0) (70% of patients) were more liable for CS (53.6%)
and CS and SGA (25%).

– Score (I) (25% of patients) were liable for CS (20%) and
SGA (30%) and preterm labor and SGA (40%).

– Score (II) (5% of patients) were highly significant for
CS and preterm labor (100%).

– In general it was significant for CS and SGA.

\( X^2 \) and \( P \) value were highly significant for the CS as preg-
nancy outcome more than preterm labor and SG.

The relation between placental score and the pregnancy
outcome is presented in Table 4 and Graph III which revealed
the followings: score (0) was seen in 62.5% of patients and
those were more liable to CS delivery as an outcome, score
(1) in 20% and score (2) in 12.5% while score 3 in 5%.

Graph V showed receiver operating characteristic (ROC)
curve of umbilical, uterine and placental scores in relation to
small for gestational age as a pregnancy outcome according
to (ROC) all three tests were sensitive to the SGA as a preg-
nancy outcome in high risk pregnancy, but placental score
was the most sensitive one according to the area under
(ROC). According to the (ROC), all tests were sensitive and
specific for high degree to predict the preterm delivery as a
pregnancy outcome in high risk pregnancy but the placental
score had the largest area under the were and was the most
accurate one (Graph VI).

4. Discussion

High-risk pregnancy is broadly defined as one in which the
mother and/or fetus will be at increased risk for morbidity
or mortality before or after delivery (15).

Examination of umbilical and uterine-arterial arterial wave-
forms by Doppler ultrasound has presented a new and exciting
method of investigation in the management of pregnancy.

In the current study, we investigated the blood flow velocity
resistance in both umbilical and uterine arteries as a more
accurate method to predict the pregnancy outcome in high-risk
pregnancy (small for gestational age (SGA), premature deliv-
ery (<37 weeks, and cesarean section). All patients were inves-
tigated during the 3rd trimester of the pregnancy. We
considered S/D ratio of umbilical artery <3 with forward dia-
stolic flow as a normal value and used it as a low risk factor.

About uterine artery score, we considered the upper limit of
PI should be 1 and below. The present study comprises a het-
erogeneous group of high risk pregnancies. The aim is to relate
the new scores to well defined outcome variables of clinical sur-
veillance for high risk pregnancies.

Umbilical artery flow velocity waveforms reflect placental
impedance to blood flow and that changes of flow patterns
may be caused by alteration of the feto-placental vessels tree
(vasoconstriction and villous infraction), therefore it could
be anticipated that fetus with an elevated systolic diastolic ra-
tio is more likely to have perinatal problems than a fetus with
normal flow pattern (16).
The present study showed that 75% and 25% of the studied subjects for umbilical artery flow were involved in score (0) and (I), respectively and the score in general was significant for the CS and SGA more than for preterm labor. No absent or reversed diastolic blood flow was noted.

Kotini et al. in 2005, studied the correlation between biomagnetic and Doppler findings of umbilical artery in IUGR and concluded that values of umbilical artery is proved to be helpful for the evaluation of fetal well-being especially in pregnancies complicated with preclampsia and growth restriction (17).

Raio et al. in 2003, studied the role of Doppler of umbilical artery in 84 pregnant ladies with IGUR and found worsening umbilical artery Doppler parameters (18).

Most of those authors concluded that an umbilical blood flow study by Doppler in 3rd trimester is very useful in predicting fetal outcome.

We found that the group of the zero score of umbilical artery Doppler was still liable to abnormal outcomes including: CS delivery (50%), babies small for age, SGA (20%) and combined CS and SGA in 23%.

Regarding the uterine artery score, all the patients were included in scores (0), (I) or (II). Yet no patient was found in categories (III), (IV) a finding that may be explained by the relatively small number of the studied patients.

We found that uterine artery score can predict the CS and SGA as pregnancy outcomes in (>42.5% and >15%), respectively, more than predicting preterm.

Most studies concluded that umbilical artery Doppler is more significant and accurate in predicting the pregnancy outcome than the uterine artery Doppler. However the uterine artery Doppler is unique in its ability to predict only severe adverse pregnancy outcome, namely placental abruption, fetal death, and pre-term delivery, so that it can be used as a continuous screening variable so as to make risk prediction specific to

<table>
<thead>
<tr>
<th>Umbilical artery score</th>
<th>Uterine artery score</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0)</td>
<td>(0)</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>83.3%</td>
<td>16.7%</td>
<td>75%</td>
</tr>
<tr>
<td>(I)</td>
<td>(I)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>30%</td>
<td>50%</td>
<td>25%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>70%</td>
<td>25%</td>
<td>5%</td>
</tr>
</tbody>
</table>

Table 1 Distribution of umbilical artery score and uterine artery score among all patients (n = 40).

<table>
<thead>
<tr>
<th>Umbilical artery score</th>
<th>Pregnancy outcome</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CS, preterm</td>
<td>SGA</td>
</tr>
<tr>
<td>(0)</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>20%</td>
</tr>
<tr>
<td>(I)</td>
<td>2</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>0%</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>42.5%</td>
<td>15%</td>
</tr>
</tbody>
</table>

$X^2 = 26.32$, $P$-value = 0.00 (statistically significant $P$-value < 0.05).

Graph I Distribution of umbilical artery score in relation to pregnancy outcome.

Pregnancy outcome

- Operative delivery (C.S.)
- Preterm delivery
- Small for gestational age

Dot/Lines show percents
Table 3  Relation between uterine artery score and pregnancy outcome among all patients ($n = 40$).

<table>
<thead>
<tr>
<th>Uterine artery score</th>
<th>Pregnancy outcome</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CS</td>
<td>Preterm delivery</td>
</tr>
<tr>
<td>(0)</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>53.6%</td>
<td>3.6</td>
</tr>
<tr>
<td>(I)</td>
<td>2</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>0%</td>
</tr>
<tr>
<td>(II)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>42.5%</td>
<td>2.5%</td>
</tr>
</tbody>
</table>

$\chi^2 = 33.36, P\text{-value} = 0.00$ (statistically significant $P\text{-value} < 0.05$).

Table 4  Relation between placental score and pregnancy outcome among all patients ($n = 40$).

<table>
<thead>
<tr>
<th>Placental score (PLS)</th>
<th>Pregnancy outcome</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CS</td>
<td>Preterm delivery</td>
</tr>
<tr>
<td>(0)</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>52%</td>
<td>4%</td>
</tr>
<tr>
<td>(I)</td>
<td>4</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>0%</td>
</tr>
<tr>
<td>(II)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>(III)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>42.5%</td>
<td>2.5%</td>
</tr>
</tbody>
</table>

$\chi^2 = 54.23, P\text{-value} = 0.00$ (statistically significant $P\text{-value} < 0.05$).
an individual patient (19,20). On the other hand it has been mentioned that the increase in feto-maternal vascular resistance is normally fourfold more frequent in the uterine than umbilical artery, this might reflect that, an increase in the resistance of the vascular blood flow could be detected earlier in the utero-placental circulation than in the feto-placental circulation (2,10).

The new uterine artery score does not take into account the location of the placenta by combining the uterine and umbilical scores and generating the placental score which is a measure of general placental vascular resistance, as simplifying the evaluation of Doppler velocimtries on both sides of the placenta.

**Graph IV**  Receiver Operating Characteristic (ROC) curve of umbilical, uterine and placental scores in relation to Cesarean section as a pregnancy outcome.

*Area under the curve for placental score is 0.713
*Area under the curve for uterine artery score is 0.431
*Area under the curve for umbilical artery score is 0.560

In our study and according to the results which done by (ROC) statistical system, we can conclude that the placental score was the most accurate one to predict the pregnancy outcome in high-risk pregnant patients.
This finding was in accordance to other study done by Gudmundsson et al. in 2003, which concluded that Doppler velocimetry on both sides of the placenta showed a strong relationship to an adverse outcome of pregnancy (2).
Giguère et al. (2010) concluded that combination of some biochemical and Doppler assessment of uterine artery have shown promising predictive performance for early identification of pregnant women at risk for preeclampsia (21).

Based on the results of the present study we can conclude that combining the Doppler umbilical artery score (blood flow classes, BFC) and the uterine artery score (UAS) to create a new placental score (PLS) showed a better relationship to predict adverse perinatal outcome in high risk pregnancy.

References