# Total Vascular Resistance and Left Ventricular Morphology as Screening Tools for Complications in Pregnancy

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***Abstract***—We evaluated the predictive value of elevated total vascular resistance on the outcome of pregnancy in normotensive high-risk primigravidas with bilateral notching of the uterine artery Doppler. A total of 526 high-risk primigravidas referred to the obstetrics outpatient clinic of Tor Vergata University with bilateral notching of the uterine artery at 20 to 22 weeks' gestation were submitted to a maternal echocardiographic examination and uterine artery Doppler evaluation at 24 weeks' gestation. Blood pressure was recorded at the time of the examination, total vascular resistance was calculated, and the geometric pattern of the left ventricle was assessed. Patients were followed until the end of pregnancy to detect fetal/maternal adverse outcomes (gestational hypertension, preeclampsia, abruptio placentae, fetal growth restriction, perinatal death, etc). A total of 111 of the 526 pregnancies showed a bilateral notch at 24 weeks' gestation, and 97 had an adverse outcome (18.44%). The best independent predictor for maternal and fetal complications was total vascular resistance (odds ratio: 91.25; 95% CI: 39.64 to 210.05; $P<0.001$). The cutoff value was 1400 dynes · s · cm$^{-5}$, with a sensitivity and a specificity of 89% and 94%, respectively. A high relative wall thickness of the left ventricle (>0.37; odds ratio: 2.47; 95% CI: 1.12 to 5.44) and a hypertrophized ventricle (left ventricular mass >130 g; odds ratio: 2.52; 95% CI: 1.12 to 5.64) were also independent predictors ($P<0.05$). Echocardiography might identify at 24 weeks' gestation patients who subsequently develop maternal and fetal complications through the assessment of maternal hemodynamics and left ventricular geometry. **(*Hypertension*. 2008;51:1020-1026.)**

**Key Words:** hypertrophy/remodeling ■ pregnancy ■ preeclampsia ■ fetal growth restriction ■ hemodynamics



Extensive research over the past 20 years has evaluated the use of uterine artery Doppler evaluation in the second[1–6] trimesters of pregnancy as a screening tool to predict the later development of preeclampsia, fetal growth restriction (FGR), placental abruption, and stillbirth. Since the introduction of uterine artery Doppler as an early screening test for complications in pregnancy in the mid-1980s, conflicting results on its value have been reported as discussed by Papageorghiou et al.[4] The persistence of bilateral notches in uterine arteries associated with a quantitative resistance index cutoff at 24 weeks' gestation was reported to improve screening efficacy to identify patients at risk for complications in pregnancy.[1,7,8]

The main problem is that second-trimester Doppler ultrasound evaluation of the uteroplacental circulation in asymptomatic patients (screening test) has been widely reported to have high-negative (97% to 99%) and low-positive predictive values for gestational hypertension and FGR (25% to 30%).[1,9–12]

Pregnancy is characterized by important changes in the maternal cardiovascular system. In recent years, maternal cardiac function was studied in normal and complicated pregnancy obtaining important information on systolic and diastolic function and on morphological parameters of the left ventricle.[13–23] In particular total vascular resistance (TVR) was found to be an important parameter in the early identification of hypertensive patients who subsequently developed complications.[22] In our previous pilot study,[24] we observed that normotensive high-risk patients with bilateral notch of the uterine arteries who subsequently showed abnormal outcome of pregnancy had higher TVR compared with the normal-outcome group.

We designed a study to evaluate the predictive value for subsequent maternal and/or fetal complications of TVR and morphological characteristics of the left ventricle detected through maternal echocardiography in normotensive high-risk primigravidas with bilateral notch of the uterine artery at 20 to 22 weeks gestation.

## Methods

### Patient Selection

A total of 608 consecutive normotensive high-risk primigravidas referred to the outpatient clinic of Tor Vergata University for the finding of bilateral notching of the uterine artery between 20 to 22 weeks' gestation were recruited between 2002 and 2006.

Inclusion criteria were as follows: (1) normal blood pressure values at enrollment; (2) absence of proteinuria at the urine analysis at the moment of enrollment; (3) normal blood sample analysis; (4)

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an estimated fetal weight >10th percentile; and (5) normal fetal Doppler parameters and amniotic fluid index. Exclusion criteria included the following: (1) undetermined gestational age; (2) tobacco use; (3) twin pregnancies; (4) maternal heart disease; (5) pre-existing maternal chronic medical problems; (6) chromosomal and/or suspected ultrasound fetal abnormalities; and (7) persistence of elevated blood pressure values (>140/90 mm Hg) 3 months after delivery.

All of the patients underwent uterine artery color Doppler examination and maternal echocardiographic evaluation at 24 weeks gestation. Approval of the university ethics committee was obtained, and written informed consent was collected from all of the patients. Patients were followed until term to verify the fetoneonatal and maternal outcomes. Gestational hypertension was diagnosed according to the definition of Davey and MacGillivray.[25] FGR was diagnosed when birth weight was <10th centile for gestational age of the reference population,[26] and a cessation or slowing of fetal growth was present associated to Doppler indicators of fetal deterioration (abnormal Ductus Venosus [DV] velocity and umbilical artery [UA] flow).

## Fetal and Uterine Artery Ultrasound Examination

For all of the ultrasound examinations, a 3.5-MHz sector ultrasound transducer interfaced to a Toshiba Xario (Toshiba Medical Systems Corp) or a Technos Esaote (Esaote Biomedica) ultrasound machine was used with the high-pass filter at 100 Hz.

All of the patients underwent uterine artery color Doppler examination at 24 weeks gestation, as described previously.[20–24] Notching of the uterine arteries was noted either bilaterally or monolaterally. Fetal biometry and estimated fetal weight were assessed according to the local reference values.[26] Fetal Doppler measurements were obtained from DV and UA.

## Echocardiographic Evaluation

The M-mode, 2D, and Doppler echocardiographic investigation, evaluating TVR, systolic, and morphological parameters of the left ventricle, was performed within 24 hours from the diagnosis bilateral notching. The M-mode, 2D, and Doppler echocardiographic evaluations were performed with the patient in lateral position in harmonic imaging with a Toshiba Xario or a Technos Esaote ultrasound machine. Left ventricular end-diastolic and end-systolic diameters and interventricular septum and posterior wall diastolic thicknesses were detected in the parasternal long axis view during M-mode tracing, according to the recommendation of the American Society of Echocardiography.[27] Left ventricular mass (LVM) in grams was calculated by the Devereux formula.[28]

## Left Ventricular Geometric Pattern

LVM index (LVMi) was then calculated as follows: LVMi=LVM/$m^{2.7}$, where m was the height of the patient in meters.[29] Relative wall thickness (RWT) was calculated as the ratio of (interventricular septum diastolic thickness+posterior wall diastolic thickness)/left ventricular end-diastolic diameter.[20]

## Systolic Function

Stroke volume (SV) was calculated as the product of aortic valve area and the aortic flow-velocity time integral, as described previously.[20] Cardiac output (CO) was calculated as the product of SV and heart rate derived from electrocardiographic monitoring.

## TVR

At the end of the maternal echocardiographic examination, systolic and diastolic blood pressure (SBP and DBP, respectively) were measured from the brachial artery with a manual cuff. TVR was calculated in dynes · s · $cm^{-5}$ according to the following formula:

$$TVR = (MBP[mm\ Hg]/CO[L/min]) \times 80$$

where MBP was mean blood pressure calculated as DBP+(SBP−DBP)/3.

## Planimetric Study of Left Atrial Maximum and Minimum Areas

From a 2D standard apical 4-chamber view, planimetry of both maximum and minimum left atrial areas were obtained through the integrated software of the ultrasound machine. Assessment of left atrial function was obtained through left atrial fractional area change.

## Outcome

The evolution of gestation was followed until term by an investigator, blinded as to the results of maternal echocardiography, to determine the outcome of pregnancy that was classified as complicated when ≥1 of the following adverse maternal and fetoneonatal outcomes occurred: (1) the occurrence of moderate or severe gestational hypertension (American College of Obstetricians and Gynecologists)[30]; (2) the occurrence of proteinuria >300 mg per 24 hours associated to a stable increase of blood pressure over 140/90 mm Hg (preeclampsia); (3) abruptio placentae; (4) other maternal complications: occurrence of thrombocytopenia, elevated liver enzymes, HELLP syndrome, and coagulation abnormalities; (5) FGR; (6) admittance to neonatal intensive care unit; or (7) perinatal death.

## Postpartum Control

All of the patients were submitted to a clinical evaluation and an echocardiographic examination 6 to 8 months after delivery to assess maternal TVR and left ventricular morphological parameters.

## Statistical Analysis

Patients were classified as either uneventful or complicated. Values are expressed as means±SDs.

Comparisons between groups were performed through 1-way ANOVA, whereas intragroup comparisons between pregnancy and postpartum data were performed through ANOVA for repeated measurements. Mann–Whitney U test was used for nonnormally distributed data.

Receiver operating characteristic (ROC) curves were built, and $\chi^2$ tests were performed for TVR, RWT, SBP, DBP, MBP, and LVM to find the optimal cutoff to identify subsequently complicated pregnancies. Accuracy of the test was used to identify the best cutoff. Accuracy was calculated according to the following formula:

$$(\text{true-positive}+\text{true-negative})/(\text{true-positive}+\text{true-negative}+\text{false-positive}+\text{false-negative}).$$

Univariate and multivariate binary logistic regression analysis were used to find predictors of maternal and/or fetal complications. The analysis univariate included the following: (1) family history of preeclampsia, diabetes, premature vascular disease, or autoimmune or renal disorders; (2) age of >35 years; (3) persistent bilateral notch of the uterine arteries; (4) RWT on the basis of the cutoff found for the studied population; (5) SBP on the basis of the cutoff found for the studied population; (6) DBP on the basis of the cutoff found for the studied population; (7) MBP on the basis of the cutoff found for the studied population; (8) LVM on the basis of the cutoff found for the studied population; and (9) TVR on the basis of the cutoff found for the studied population. Among SBP, DBP, MBP, and TVR, only the best predictor was included in the multivariate analysis, because they are related to each other in the TVR and MBP formulas.

To test intraobserver and interobserver variability, 2 independent observers measured data on videotape recordings from 20 randomly selected patients. The same data were than remeasured on tape after 1 month by 1 of the 2 observers.

# Results

Seventy-nine patients were excluded from the study because of missing follow-up data for pregnancy or postpartum, and 3 patients showed hypertension 3 months after delivery, for a total of 82 patients excluded from the analysis. A total of 111

**Table 1. Main Maternal and Fetal/Neonatal Complications Subsequently Developed in Asymptomatic Patients With Bilateral Notching at 24 Weeks**

| Complications Occurred in the Study Group | N, 97 of 526 |
|---|---|
| Maternal complications | 41 |
| Appearance of proteinuria >300 mg per 24 hours and blood pressure >140/90 mm Hg (preeclampsia) | 19 |
| Evolution towards moderate-to-severe GH with induced preterm delivery <34 wk | 15 |
| Abruptio placenta | 3 |
| HELLP syndrome (2 patients), coagulation abnormalities (1 patient), thrombocytopenia (1 patient) | 4 |
| Fetal/neonatal complications | 26 |
| FGR | 18 |
| Admittance to NICU | 6 |
| Perinatal death | 2 |
| Maternal and fetal/neonatal complications | 30 |
| Preeclampsia and fetal growth restriction | 20 |
| Evolution toward moderate-to-severe GH and FGR with induced preterm delivery <34 wk | 9 |
| HELLP syndrome and neonatal death | 1 |
| Total complications | 97 |

GH indicates gestational hypertension; NICU, neonatal intensive care unit.

(21.1%) of the remaining 526 patients included in the study had a persistent bilateral notch; 89 (16.9%) showed a monolateral notch; and 326 (62.0%) had a normal uterine artery Doppler at 24 weeks gestation. Of 526 pregnancies reviewed after delivery, 429 patients (81.6%) had an uneventful pregnancy, and 97 patients (18.4%) showed a subsequent development of maternal and/or fetal complications.

Table 1 shows the main complications developed after the enrollment in the study: 41 pregnancies showed isolated maternal complications and 26 pregnancies had isolated fetal-neonatal complications, whereas 30 were characterized by both maternal and fetal complications. Table 2 shows the baseline characteristics of the patients at enrollment retrospectively classified as uneventful and complicated. The complicated primigravidas gave birth earlier to neonates of lower birth weight centiles compared with the uneventful group. Table 3 shows the hemodynamic and left ventricular morphological features of uneventful and subsequently complicated patients at enrollment (24 weeks) and at 6 to 8 months after delivery.

Intragroup comparisons in the uneventful group showed lower SBP. DBP, MBP, TVR, higher maternal heart rate, RWT, LVMi, SV, CO, and left atrial fractional area change at 24 weeks gestation compared with postpartum. Intragroup comparisons in the complicated group gave evidence of lower SBP, DBP, mean arterial pressure, SV, and CO and higher TVR, LVMi, and RWT during pregnancy versus the postpartum values.

Intergroup comparisons at 24 weeks gestation between complicated and uneventful patients showed SBP, DBP, and MBP slightly higher in the complicated compared with the uncomplicated group. Heart rate, SV, CO, and left atrial fractional area change were lower, whereas TVR was higher



**Table 2. Baseline Features of the 2 Groups**

| Parameter | Uncomplicated n=429 | Complicated n=97 | *P* |
|---|---|---|---|
| Age, mean±SD, y | 33±4 | 34±4 | 0.021 |
| Age >35 y, n (%) | 157 (36.6) | 49 (50.5) | 0.016 |
| Height, mean±SD, m | 1.64±0.06 | 1.63±0.06 | NS |
| Prepregnancy body mass index, mean±SD, kg/m$^2$ | 24.0±2.0 | 24.1±2.0 | NS |
| Family history, n (%) | 171 (39.9) | 50 (51.5) | 0.048 |
| Bilateral notch of the uterine artery at 24 weeks gestation, n (%) | 69 (16.1) | 42 (43.3) | <0.001 |
| Gestational age at delivery, mean±SD, wk | 38±1 | 32±4 | <0.001 |
| Neonatal weight centile, mean±SD | 45±23 | 18±14 | <0.001 |

NS indicates not significant.

in the complicated compared with the normal-outcome group. LVMi and RWT were higher in the complicated group with respect to uneventful pregnancies.

For intergroup comparisons 6 to 8 months after delivery, DBP and MBP were slightly higher in the complicated compared with the uncomplicated group. TVR was higher in the complicated compared with the normal-outcome group. LVMi and RWT were slightly higher in the complicated group with respect to uneventful pregnancies.

The best cutoff value for TVR in the identification of adverse fetomaternal complications was 1400 dyn · s · cm$^{-5}$ and showed sensitivity at 89%, specificity at 94%, a Positive predictive value (PPV) at 77%, and a negative predictive value (NPV) at 97%. The best cutoff value for RWT was 0.37 and showed sensitivity at 70%, specificity at 84%, a PPV at 50%, and NPV at 93%. In this high-risk population, bilateral notch of the uterine artery had a sensitivity at 43%, specificity at 84%, a PPV at 38%, and NPV at 87%. The cutoff value for SBP was 120 mm Hg, with a sensitivity at 53%, specificity at 65%, a PPV at 26%, and NPV at 86%; for DBP it was 69 mm Hg, with sensitivity at 49%, specificity at 71%, a PPV at 28%, and NPV at 86%; for MBP, it was 82 mm Hg, with sensitivity at 57%, specificity at 62%, a PPV at 26%, and NPV at 86%; for LVM, it was 130 g, with sensitivity at 59%, specificity at 62%, a PPV at 26%, and NPV at 87%. Table 4 reports sensitivity, specificity, PPV, NPV, and accuracy of the different cutoff values for TVR.

The univariate and multivariate analyses are reported in Table 5. Among TVR, SBP, DBP, and MBP, TVR was the best predictor for subsequent complications and was included in the multivariate model. TVR, LVM, and RWT appeared to be independent predictors of complicated pregnancies, although the best predictor was TVR.

## Interobserver and Intraobserver Variability

Intraobserver and interobserver variability in terms of the coefficient of variation and regression coefficient are reported. For the interventricular septum thickness, the coefficients of variation were 7.1% ($r$=0.98) and 7.5% ($r$=0.96) for intraobserver and interobserver error, respectively. For the

**Table 3. M-Mode– and 2D-Derived Parameters at 24 Weeks Gestation and 6 to 8 Months Postpartum**

| | Uncomplicated (N=429) | | Complicated (N=97) | |
|---|---|---|---|---|
| Parameter | 24 Weeks Gestation | 6 to 8 Months Postpartum | 24 Weeks Gestation | 6 to 8 Months Postpartum |
| Heart rate | 80±11* | 74±9 | 75±13† | 75±11 |
| SBP, mm Hg | 115±11* | 119±11 | 119±12 | 122±11 |
| DBP, mm Hg | 62±11* | 68±11 | 66±12*† | 70±13† |
| MBP, mm Hg | 80±9† | 85±9 | 84±10*† | 88±10† |
| TVR, dynes · s · $cm^{-5}$ | 1009±228* | 1359±281 | 1570±317*† | 1447±312† |
| LVM, g | 124±22* | 96±19 | 140±32*† | 112±23† |
| LVMi, $g/m^{2.7}$ | 33±6* | 25±5 | 38±9*† | 30±7† |
| LVDd, cm | 4.83±0.30* | 4.63±0.28 | 4.58±0.32*† | 4.62±0.28 |
| IVSd, cm | 0.80±0.09* | 0.70±0.09 | 0.93±0.10*† | 0.78±0.09† |
| PWd, cm | 0.76±0.11* | 0.64±0.10 | 0.88±0.13*† | 0.74±0.9† |
| RWT | 0.32±0.05* | 0.29±0.04 | 0.40±0.05*† | 0.33±0.04† |
| SV, mL | 82±13* | 70±12 | 61±14*† | 68±13 |
| CO, L | 6.57±1.25* | 5.17±0.96 | 4.51±1.33* | 5.05±1.21 |
| LA max, $cm^2$ | 15.7±2.6* | 14.7±2.7 | 14.5±2.7† | 14.3±2.7 |
| LA min, $cm^2$ | 7.6±1.5* | 8.1±1.9 | 8.2±2.0† | 8.1±2.0 |
| LA FAC, % | 52±6* | 43±11 | 43±10† | 42±9 |

LA indicates left atrial; max, maximum; min, minimum; FAC, fractional area change; LVDd, left ventricular end-diastolic diameter; IVSd, interventricular septum diastolic thickness; PWd, posterior wall diastolic thickness.

*$P<0.05$ intragroup comparison (24 weeks gestation uneventful vs 6 to 8 months postpartum uneventful; 24 weeks' gestation complicated vs 6 to 8 months postpartum complicated).

†$P<0.05$ intergroup comparison (24 weeks gestation uneventful vs 24 weeks gestation complicated; 6 to 8 months postpartum uneventful vs 6 to 8 months postpartum complicated.



posterior wall thickness, they were 8.2% ($r=0.98$) and 7.9% ($r=0.98$), for the left ventricular diastolic diameter they were 4.9% ($r=0.97$) and 7.5% (0.98), for the left ventricular systolic diameter they were 7.0% ($r=0.98$) and 8.2% ($r=0.96$), for the LVM they were 8.9% ($r=0.95$) and 9.0% ($r=0.94$), and for the TVR they were 7.4% ($r=0.97$) and 8.0% ($r=0.96$).

## Discussion

The novel finding of this study is that TVR seems to be the best screening test for complications in normotensive high-risk 24-weeks primigravidas, giving better results compared with the standardized uterine Doppler ultrasound evaluation usually performed by obstetricians.

Uterine Doppler waveforms analysis has become a valuable tool in the evaluation of the placental circulation and in the prediction of pregnancy outcome. Increased placental vascular impedance is frequently related to FGR and pregnancy-induced hypertension,[1,3,6,7–12] which are still unsolved severe clinical problems associated with an increased maternal and perinatal mortality and morbidity. Maternal uterine artery Doppler in the second trimester of pregnancy helps the obstetricians to select patients at high risk for these complications but with a too low positive predictive value. In fact, women with elevated uterine artery resistance index and/or uterine artery notching in the second trimester may go on to have a normal pregnancy. In the last decades, the effort was focused in the association of biochemical, humoral, and other instrumental methods[30–35] in an attempt to improve the PPV of the uteroplacental screening test. To date, the obtained results are not enthusiastic and conflicting. Moreover, the obstetricians have not yet identified a cheap and reliable screening test for complications in pregnancy.

These considerations have prompted us to look at maternal cardiac morphological parameters and vascular function during pregnancy and its relationship with uterine artery Doppler in the second trimester. In physiological pregnancies, reduction in uteroplacental resistance index, because of the remodelling of the spiral artery, is concomitant with a decrease in TVR, which represents the steady component of the afterload, and includes the uteroplacental circulation with a contribution of 20% to 26% to the total reduction of systemic vascular resistance in the second trimester.[16]

Abnormal uterine artery Doppler waveforms during the second trimester of pregnancy have been linked to an altered trophoblast invasion of the spiral arteries with an abnormal placentation process and seem to be related to several disorders of pregnancy, such as FGR and preeclampsia. In the last decade, an altered cardiovascular adaptation was noted in patients with such complications.[18–24] In the present study, many cardiovascular parameters were found to be altered in normotensive mothers with the subsequent development of complications.

It is interesting to note that at 24 weeks gestation, the SBP, DBP, and mean arterial pressure values were slight higher in

**Table 4. Cutoff Values for TVR at 24 Weeks Gestation in the Prediction of Subsequent Adverse Outcomes in Pregnancy**

| Cutoff | Specificity, % | Sensitivity, % | Accuracy, % | PPV, % | NPV, % |
|---|---|---|---|---|---|
| 600 | 0.70 | 97.94 | 18.63 | 18.23 | 60.00 |
| 700 | 3.96 | 95.88 | 20.91 | 18.42 | 80.95 |
| 800 | 12.82 | 94.85 | 27.95 | 19.74 | 91.67 |
| 900 | 34.97 | 93.81 | 45.82 | 24.59 | 96.15 |
| 1000 | 57.34 | 92.78 | 63.88 | 32.97 | 97.23 |
| 1100 | 71.33 | 91.75 | 75.10 | 41.98 | 97.45 |
| 1200 | 82.98 | 90.72 | 84.41 | 54.66 | 97.53 |
| 1300 | 92.07 | 89.69 | 91.63 | 71.90 | 97.53 |
| 1350 | 93.47 | 89.69 | 92.78 | 75.65 | 97.57 |
| 1370 | 93.71 | 89.69 | 92.97 | 76.32 | 97.57 |
| 1380 | 93.94 | 89.69 | 93.16 | 76.99 | 97.58 |
| 1390 | 93.94 | 88.66 | 92.97 | 76.79 | 97.34 |
| 1400 | 94.17 | 88.66 | 93.16 | 77.48 | 97.35 |
| 1430 | 94.64 | 84.54 | 92.78 | 78.10 | 96.44 |
| 1450 | 95.10 | 79.38 | 92.21 | 78.57 | 95.33 |
| 1500 | 95.80 | 67.01 | 90.49 | 78.31 | 92.78 |
| 1600 | 97.44 | 50.52 | 88.78 | 81.67 | 89.70 |
| 1700 | 97.90 | 31.96 | 85.74 | 77.50 | 86.42 |
| 1800 | 99.07 | 16.49 | 83.84 | 80.00 | 83.99 |
| 1900 | 99.53 | 11.34 | 83.27 | 84.62 | 83.24 |
| 2000 | 99.53 | 4.12 | 81.94 | 66.67 | 82.12 |

patients with subsequent complications compared with the uneventful group, although in the normotensive range. Maternal heart rate and SV were also different between groups, being lower in the complicated group as for a lack of an upregulation of the cardiovascular system, which should characterize pregnancy. The overall result was a greatly lower CO and higher TVR in patients with subsequent development of an abnormal outcome of pregnancy, as described previously.[24] Another important finding that emerged from our results is the depressed left atrial function in the complicated compared with the uneventful pregnancies. Left ventricular morphological parameters were also different at 24 weeks gestation with a more concentric geometry and hypertrophized ventricle in the subsequently complicated pregnancies.

All of these data suggest that the signs of an altered maternal adaptation to pregnancy resides inside the whole cardiovascular system before the real appearance of a maternal and/or fetal disease. In a previous study on early mild gestational hypertension,[22] we found that, among the cardiovascular parameters, TVR and concentric geometry were predictive for complications. Because in the present study the differences in cardiovascular adaptation seem to be present also in an earlier stage (before complications occur), we tested these parameters as a screening test comparing them with the uterine artery Doppler evaluation.

The receiver operating characteristic curve for TVR showed that the best value for complications in pregnancy was 1400 dynes with a PPV of 77%, which is, to date, among the highest values reported in literature obtained by a single cheap and available instrumental screening method. The multivariate analysis showed that TVR is the best independent predictor for the identification of subsequent development of complications in pregnancy. Moreover, as we can observe by TVR receiver operating characteristic curves (Table 4), the value of accuracy remains stable at ≈93% inside the range of 1350 to 1430 dynes. Obstetricians should, therefore, consider a pregnant patient at high risk for complications when the value of TVR is around this range, increasing the clinical control of the mother and the fetus.

Other interesting results related to the difference between antepartum and postpartum data are the different hemodynamic features of the 2 groups. Simmons et al[36] reported that women with preeclampsia tend to decrease their TVR, whereas normotensive women show an increase from antenatal to postpartum. Our report is consistent with those previous

**Table 5. Univariate and Multivariate Binary Logistic Regression Analysis for the Prediction of Complicated Pregnancy**

| Regression Analysis | Predictor | Odds Ratio | 95% CI | *P* |
|---|---|---|---|---|
| Univariate analysis | Family history | 1.61 | 1.03 to 2.50 | 0.036 |
| | Age (>35 y) | 1.77 | 1.13 to 2.76 | 0.012 |
| | Bilateral notch of the uterine arteries | 3.98 | 2.47 to 6.42 | 0.000 |
| | Concentric geometry (RWT ≥0.37) | 11.67 | 7.02 to 19.38 | 0.000 |
| | SBP (>120 mm Hg) | 1.68 | 1.03 to 2.50 | 0.022 |
| | DBP (>69 mm Hg) | 1.97 | 1.26 to 3.07 | 0.003 |
| | MBP (>82 mm Hg) | 1.88 | 1.21 to 2.94 | 0.005 |
| | LVM (>130 g) | 2.40 | 1.53 to 3.75 | 0.000 |
| | TVR (≥1400 dynes · s · $cm^{-5}$) | 126.34 | 59.90 to 266.50 | 0.000 |
| Multivariate analysis | Family history | 1.51 | 0.49 to 4.66 | 0.474 |
| | Age (>35 y) | 0.88 | 0.28 to 2.79 | 0.834 |
| | Bilateral notch of the uterine arteries | 1.48 | 0.65 to 3.35 | 0.351 |
| | Concentric geometry (RWT ≥0.37) | 2.47 | 1.12 to 5.44 | 0.026 |
| | LVM (>130 g) | 2.52 | 1.12 to 5.64 | 0.025 |
| | TVR (≥1400 dynes · s · $cm^{-5}$) | 91.25 | 39.64 to 210.05 | 0.000 |

findings. Moreover, the finding of an elevated postpartum TVR and BP values in all of the women with an abnormal outcome compared with the uneventful group might indicate a possible pregestational predisposition to pregnancy complications, as hypothesized previously.[22,23] This hypothesis is strengthened in this study by the fact that differences in left ventricular morphological parameters and TVR were still present 6 to 8 months postpartum.

Our study shows that, before complications appear, the maternal vascular function and cardiac morphology of pregnant patients destined to have complications differ dramatically from those destined to have a normal outcome of pregnancy and that this cardiovascular dissimilarities might be used to reliably classify them, in particular through TVR. Thus, if these results will receive further confirmation, the echocardiographic analysis of maternal cardiac morphology and vascular function may be of help for the solution to the problem of the false-positive rate of the uterine artery Doppler screening test, which normally concerns the obstetricians.

## Perspectives

This study shows that maternal left ventricular morphological parameters and vascular function derived from echocardiography might help in the reliable identification of pregnant patients subsequently developing severe complications. The knowledge of underling cardiac and vascular mechanisms probably involved in the deterioration of maternal and/or fetal well being might be of help in the management of these patients in the preclinical phase of the disease. In particular, the reduction of TVR through therapy might be a target for treatment more than blood pressure alone, even before the appearance of the complication. Because at the basis of the adverse outcome of these pregnancies there is often an abnormal placentation process probably favored by a genetic predisposition, the possible effect of an early treatment might be limited to an improvement of the outcome delaying the complication more than avoiding it. We think that, if these data receive further confirmation, the next step should be the application of maternal echocardiographic parameters to the therapeutic management.

## Disclosures

None.

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