

## Benefit of Placenta Accreta Equation as predictor of placental invasion in patients with Placenta Previa

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### Abstract:

**Objective:** We sought to apply a standardized evaluation of ultrasound findings and maternal characteristics as parameters for the prediction of placental invasion in a high-risk population.

**Study design:** This was a prospective review of gravidas with or without prior cesarean delivery who received an ultrasound diagnosis of placenta previa or low-lying placenta in the second and third trimester at Aleppo University Hospital for Obstetrics & Gynecology from 2017 through 2019. Sonographic images were reviewed by an investigator blinded to pregnancy outcome and sonography reports. Parameters assessed included type and location of placenta previa, loss of retroplacental clear zone, irregularity and width of uterine-bladder interface, smallest myometrial thickness, presence of lacunar spaces, bridging vessels, and measure the mean pulsatility index of uterine artery. Maternal characteristics included maternal age, number of prior cesarean delivery, abortion, parity, the story of previous combined deliveries (normal and cesarean), and severe vaginal bleeding and/or preterm labor before 34 week. Diagnosis of placental invasion was based on histologic confirmation.

**Results:** Of 196 gravidas who met inclusion criteria, 26 (13.3%) had invasion confirmed on hysterectomy specimen. All sonographic parameters were associated with placental invasion ( $P < .001$ ). Constructing a receiver operating characteristic curve, the combination of ultrasound parameters and characteristics variables, yielded an area under the curve of 0.996 ( $p < .001$ ).

Using Discriminant Analysis, a predictive equation was generated from 12 parameters, termed the "Placenta Accreta Equation." The equation was significant ( $p < .000$ ). The overall accuracy, sensitivity, specificity, and positive and negative values of PAE were 91%, 100%, 89%, 59.1%, 100%, respectively. **Conclusion:** Assignment of the Placenta Accreta Equation may be helpful in predicting individual patient risk for morbidly adherent placenta.

**Keywords:** previa. accreta. Invasion. Ultrasound.

## INTRODUCTION

Morbidly adherent placenta (MAP) defines a spectrum of conditions, including placenta accreta, increta and percreta, occurs in the complete or partial absence of the decidua basalis. which are associated with significant maternal and fetal morbidity and mortality<sup>1</sup>.

Women with previous cesarean delivery and placenta previa are known to be at greater risk of placenta accrete<sup>1,2,3</sup>. As a result of the notably increased rate of Cesarean deliveries, the reported incidence of placenta accreta has increased from approximately 0.8 per 1000 deliveries in the 1980s to 3per 1000 deliveries in the past decade<sup>4</sup>.

In clinical practice, nonseparation of the placenta at delivery leads to massive obstetric hemorrhage, resulting in maternal morbidities such as massive blood transfusion, disseminated intravascular coagulopathy, injury to the bladder and intestine, the need for hysterectomy, and even maternal death<sup>5</sup>.

Predelivery knowledge of morbidly adherent placenta is important for the development of an effective treatment strategy to minimize maternal morbidity and mortality<sup>6,7</sup>. Which allows for multidisciplinary planning and delivery before the onset of labor and/or vaginal bleeding<sup>8</sup>.

Sonography with grayscale and color Doppler imaging is the recommended first-line modality for diagnosing morbidly adherent placenta<sup>8,9,10</sup>. The diagnosis of morbidly adherent placenta involves a number of different ultrasound variables, some qualitative and others that have been quantified. These markers include an inability to visualize the normal retroplacental clear zone, irregularity and attenuation of the uterine-bladder interface, retroplacental myometrial thickness, presence of intraplacental lacunar spaces, and bridging vessels between the placenta and bladder wall when using color Doppler<sup>11,12</sup>, lower uterine artery PI in patients with placenta accreta than in normal pregnancy and placenta previa<sup>13</sup>. The physiologic changes of the spiral arteries lead to increased blood flow into the intervillous space, resulting in a progressive and substantial decrease in the mean uterine artery PI with gestation. On the other hand, inadequate physiologic changes are associated with an increased uterine artery PI, resulting in adverse pregnancy outcomes<sup>14</sup>. A histologic examination of morbidly adherent placenta specimens showed that the trophoblast had invaded the myometrium without deciduas, leading to nonseparation of the placenta and heavy bleeding<sup>15</sup>. This condition can be considered an excessive physiologic change, which

may explain the lower uterine artery PI in patients with placenta accreta than in women with normal pregnancies.

A recent metaanalysis of 23 studies explored the contribution of these ultrasound parameters to the overall prediction of morbidly adherent placenta and found a promising sensitivity of 91% and specificity of 97%.

The aim of this study was to develop a predictive equation for probability of invasion based on a combination of ultrasound parameters and clinical characteristics in a cohort of women at increased risk for placental invasion. Based on the assessment outcome, patients were offered specific antepartum and intrapartum management.

## **MATERIALS AND METHODS**

This was a prospective review of gravidas with or without prior cesarean deliveries who had sonographic confirmation of placenta previa or low-lying placenta during either the second or third trimester of pregnancy using two-dimensional (2D) grayscale imaging and color Doppler flow mapping at our ultrasound unit from July 2017 through December 2020 and were subsequently delivered at our hospital in University of Aleppo. The total number of pregnancies (alive delivery) during this period 12,737, 12521 patients with normal pregnancy, and 216 patients with placenta previa, Patients were excluded from the study if they did not deliver at our hospital, they were 20 patients, so the total number of pregnancies were included in The study was 196.

The diagnosis of placenta previa was based on the presence of placental tissue covering the internal cervical os. Low-lying placenta was diagnosed when the placenta was within 2 cm from the internal cervical os but did not cover it. Sonographic parameters evaluated from archived images included location of placenta, loss of the retroplacental clear zone, irregularity and thickness of the uterine-bladder interface, the smallest myometrial thickness in sagittal and transverse planes, presence of lacunar spaces (G0,1,2,3 according to Finberg and Williams)<sup>11</sup>, and bridging vessels. In addition to grayscale imaging, color Doppler was used in assessment of abnormal vasculature, uterine artery Doppler velocimetry were performed on the left and right uterine arteries, and the mean PI and was defined as the average of the two vessels. Cases of intrauterine growth restriction, pregnancy induced hypertension, multiple pregnancies, fetal anomalies, chromosomal abnormalities, and maternal medical illnesses such as

cardiovascular disease, renal disease, and diabetes mellitus were excluded when we estimated PI, they were 9 patients.



Figure.1: Loss of the myometrial and placental interface anteriorly.

Increased vascularity extending into myometrium (bridging vessels)

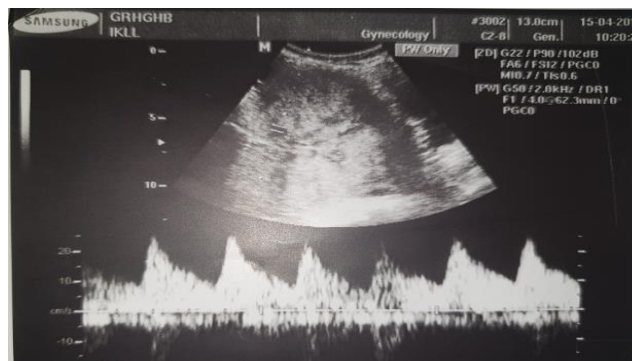


Figure.2: Placental lacunae with turbulent flow (PSV>15cm/s), G3.

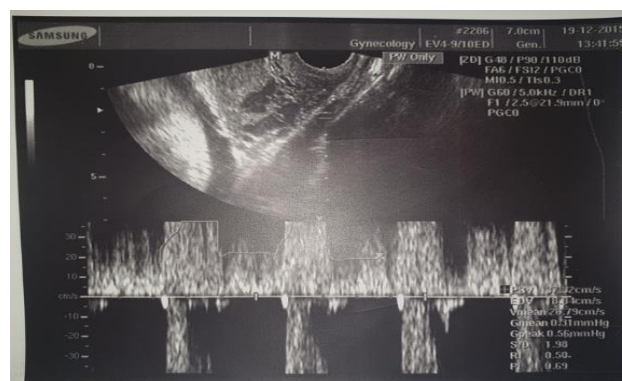


Figure.3: Uterine artery Doppler velocimetry (pulsatility index= 0.69).

The images and measurements (obtained using electronic calipers) were printed as a thermal hard copy for the patient record file. Only satisfactory ultrasound images were included for data processing. Ultrasound examinations were performed with transabdominal transducer and/or a transvaginal probe. Ultrasound images and associated reports used in the clinical management of each patient were stored electronically in a picture-archiving and communication system throughout the study period. Therefore each patient had both a hard copy and an archived electronic file of the images.

Our antenatal care approach included supplementation with oral iron to maximize iron stores and oxygen-carrying capacity. In selected patients, concurrent parenteral iron infusion was given preoperatively. Blood Products Commonly Transfused in Obstetrical Hemorrhage and whole blood for massive hemorrhage. In cases of preterm labor and/or little hemorrhage, tocolytics are given, they be limited to 48 hours of administration. After bleeding has ceased for approximately 2 days and the fetus is judged to be healthy after give Dexamethasone or Betamethasone, a woman can usually be discharged home with instructions for “pelvic rest.” Importantly, the woman and her family must fully appreciate the possibility of recurrent bleeding and be prepared for immediate transport back to the hospital. In other cases, prolonged hospitalization may be ideal.

Preoperative ultrasound mapping of the placental location was performed to assist in determining the optimal approach for abdominal wall and uterine incisions and to avoid disturbance of the placenta before delivery of the fetus.

As part of our protocol, the results of the scoring system were reported to the patients and the surgical team. In all cases of medium and high probability of MAP, a preoperative checklist was completed to confirm that the required preparations had been made and to identify the name and contact information of the consultant in case they were needed for intraoperative or perioperative assistance<sup>16</sup>. Thus patients who were classified as high probability for MAP (8or more points) underwent surgery by a highly experienced senior obstetrician and a multidisciplinary team.

According to our protocol, in all cases of moderate and high probability of MAP, preoperative consultation and notification of the blood bank was conducted and adequate access to replacement blood was secured, In the high-risk group. Patients with a Low-lying placenta were scheduled for vaginal delivery if Cesarean section was not indicated for other reasons,(just one patient). Patients with medium or high probability of MAP were scheduled for Cesarean section at 37 weeks of gestation. When gross placental invasion was evident at surgery massive bleeding occurred, the placenta was difficult to detach from the uterus or a part of the placenta remained attached, the common practice in our institute was not to attempt to remove the placenta manually and a B-Lynch procedure or Cesarean hysterectomy was performed, where appropriate. The presence and severity of placental adherence was determined by the surgeons, and the clinical descriptions were documented in the electronic patient file. The need for a hysterectomy was decided at surgery dependent on the surgical findings.

Pathological diagnoses were available only in cases that underwent wedge resection or Cesarean hysterectomy the pathologist was not blinded to the suspected diagnosis but was blinded to the sonographic score.

Of 196 patients in the final analysis, 26 (13.3%) had histologic confirmation of morbidly adherent placenta (9 placenta accrete, 16 placenta increta, 1placenta percreta), and the remaining 170 women served as the comparison group. operative procedure and maternal postoperative complications were obtained for each group. Statistical analyses were performed with SPSS Statistic version 26 software.

Analyses included participant characteristics such as maternal age, parity, history of cesarean delivery, myomectomy, abortion, placenta previa. Type of previous delivery (normal, cesarean, normal and cesarean), severe vaginal bleeding before 34weeks, smoking, gestational age at delivery. And ultrasound finding suspicion of MAP, with Doppler measurements of both uterine arteries, Uterine artery Doppler measurements were performed on the left and right uterine arteries, and the mean PI were defined as the average of the two vessels. The maternal characteristics in the study groups were compared by a Pearson or Fisher exact test for categorical variables and a Mann-Whitney U for continuous variables.

Logistic regression analysis was used to determine the maternal characteristics and obstetric risk factors by which placenta accreta could be predicted. The odds ratios (ORs) for placenta accreta were calculated for the variables suspicion of MAP .

A receiver operating characteristic curve analysis was used to examine the diagnostic

accuracy of the uterine artery PI, maternal characteristics, ultrasound finding suspicion of MAP and the combination of these values for detection of placenta accreta, and found out an optimal cut-off point of predicted probability by maximizing the Youden Index.

A two-tailed *P*-value<0.05 was considered statistically significant.

## RESULTS

Maternal characteristics are shown in Table 1:

**Table.1: Characteristics of the Placental invasion and No Placental invasion groups.**

Characteristic	Placental invasion, n=26	No placental invasion, n=170	<i>P</i> value
Maternal age	34±4.8	31±5.8	0.015
Type of previous deliveries			
Normal	0	38(22.4%)	0.014
Cesarean	12(46.2%)	76(44.7%)	
Normal + Cesarean	14(53.8%)	56(32.9%)	
Parity			
0	0	4(2.3%)	0.059
1	0	20(11.7%)	
2	3(11.5%)	21(12.3%)	
≥3	23(88.5%)	125(73.5%)	
History of cesarean delivery			
0	0	38(22.3%)	0.005
1	1(3.8%)	23(13.5%)	
2	5(19.2%)	31(18.2%)	
≥3	20(77%)	78(51.2%)	
History of abortion			
0	16(61.5%)	112(65.8%)	0.341
1	5(19.2%)	27(15.8%)	
2	3(11.5%)	17(10%)	
≥3	3(11.5%)	13(7.6%)	
Severe vaginal bleeding before 34 gestational week	7(30%)	18(10.6%)	0.02
smoking	2(7.7%)	25(14.7%)	0.334

*P*<0.05 significant. Values given as n (%) and ± (SD).

There were no differences in number of multiparous women, abortion history, or smoking between pregnancies with and without histologic evidence of placental invasion. Whereas the placental invasion group had a significantly higher mean maternal age, number of prior cesarean delivery, the story of previous normal and cesarean deliveries, and severe vaginal bleeding and/or preterm labor before 34 week. are risk factors for placental invasion. Factors such as myomectomy, endometrial ablation, IVF, prior MAP. Were not included in our study because the numbers of these cases were very rare or absent.

The accreta group had a significantly higher rate of placenta previa totalis than the previa group. Furthermore, the frequency of placenta accrete showed a statistically significant difference depending on the location of the placenta (Table 2). Among the placenta accreta group, 96% of placentas were located on the anterior wall of the uterus and 96% had complete placenta previa.

**Table.2: previa type and placental location in the Placental invasion and No Placental invasion groups.**

Characteristic	Placental invasion, n=26	No placental invasion, n=170	P value
Anterior previa placentation	25(96%)	114(67%)	0.02
Complete placenta previa	25(96%)	131(76.5%)	0.024

$P < 0.05$  significant. Values given as n (%).

Sonographic findings are presented in table3:

**Table.3: ultrasound parameters of entire cohort.**

Variable	Placental invasion, n=26	No placental invasion, n=170	P value
Lacunae			
G0	0	77(45.3%)	$< 0.001$
G1	0	55(32.3%)	
G2	3(11.5%)	31(18.2%)	
G3	23(88.5%)	7(4%)	
Bridging vessels	22(84.6%)	20(11.7%)	$< 0.001$
Sagittal smallest myometrial thickness,mm	0.94±1.31	3.7±2.52	$< 0.001$
Mean PI	0.69±0.31	1±0.38	$< 0.001$

$P < 0.05$  significant. Values given as n (%) and  $\pm$  (SD).

All sonographic parameters we assessed are  $P < 0.001$ .

Using ROC curve analysis for each characteristic and sonographic parameter predicting MAP are shown in figure 4. A cut off points for continuous parameters (myometrial thickness, PI, maternal age, the numbers of prior cesarean delivery, parity) were defined as values: ( $\leq 1.45\text{mm}$ ,  $\leq 0.685$ ,  $> 30$ ,  $\geq 2$ ,  $\geq 3$ ), respectively.

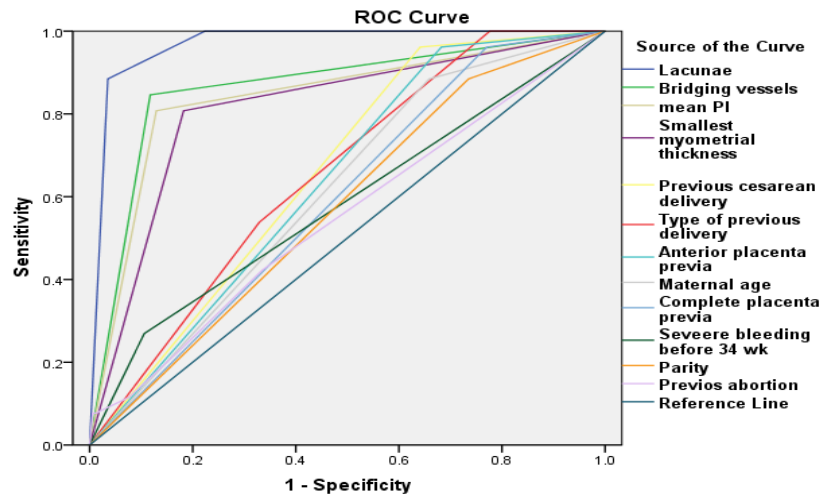


Figure.5: ROC curves for each 12 factors used in predicting MAP.

Test Result Variable(s)	Area Under the Curve			Asymptotic 95% Confidence Interval	
	Area	Std. Error <sup>a</sup>	Asymptotic Sig. <sup>b</sup>	Lower Bound	Upper Bound
Lacunae	.969	.012	.000	.946	.993
Bridging vessels	.864	.043	.000	.779	.949
mean PI	.839	.047	.000	.746	.932
Smallest myometrial thickness	.813	.048	.000	.719	.907
Previous cesarean delivery	.660	.048	.009	.567	.754
Type of previous delivery	.656	.050	.010	.558	.754
Anterior placenta previa	.640	.049	.022	.543	.737
Maternal age	.613	.053	.064	.508	.718
Complete placenta previa	.595	.053	.117	.491	.700
Severe bleeding before 34 wk	.582	.065	.180	.455	.708
Parity	.575	.056	.221	.465	.684
Previous abortion	.549	.063	.420	.426	.672

a. Under the nonparametric assumption  
 b. Null hypothesis: true area = 0.5

And the ROC curve of these 12 combined factors is better than the ROC curve of each parameter in predicting MAP (Figure 5).

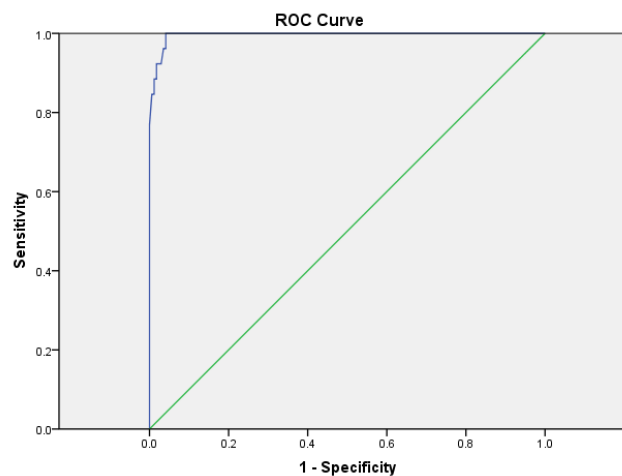


Figure.5: ROC curve for prediction of MAP using a combination of all studied variables (12).

**Area Under the Curve**

Test Result Variable(s): Predicted probability

Area	Std. Error <sup>a</sup>	Asymptotic Sig. <sup>b</sup>	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
.996	.003	.000	.000	1.000

a. Under the nonparametric assumption

b. Null hypothesis: true area = 0.5

Using variable selection by stepwise analysis, parameters most highly associated with placenta invasion in our model are presented in descending order in Table 4.

**Table.4: OR estimates and 95%CI of each parameter.**

Parameter	OR	95%CI
Grade-3 lacunae	209.5	(49-896)
Bridging vessels	41.3	(12.9-123)
Mean PI<0.685	28.255	(9.66-82.64)
myometrial thickness<1.45mm	18.83	(6.589-53.823)
History of cesarean delivery≥2	14	(1.85-105.8)
Anterior previa placentation	11.64	(1.357-88)
Complete placenta previa	7.44	(0.97-56.7)
Maternal age>30 years	3.97	(1.144-13.77)
Severe vaginal bleeding before 34 gestational week	3.11	(1.15-8.413)
Parity	2.76	(0.97-9.64)
Type of previous deliveries(combination between normal and cesarean)	2.4	(1.03-5.47)

Through Discriminant Analysis, a predictive equation, which we termed the PAE, was generated using these 12 parameters, based on the addition or weighting of each parameter. The estimated equation is defined as:

$$PAE = +0.688(\text{Grade of lacunae}) + 1.036(\text{Bridging vessels}) + 1.402(\text{PI}) + 0.092(\text{Myometrial thickness}) + 0.417(\text{number of prior cesarean delivery}) - 0.591 (\text{Location of placenta previa}) - 0.314(\text{Type of placenta previa}) + 0.174(\text{Maternal age}) + 0.688(\text{Severe bleeding before 34 wk}) - 0.181(\text{Type of previous deliveries}) - 0.1(\text{Parity}) + 0.201(\text{Abortion}) - 0.952(\text{Constant}).$$

Then we assigned a weighted value to each parameter used in our equation as shown in table 5

**Table.5: Value of each parameter is added in the Placenta Accreta Equation.**

Equation of placental invasion	> 0: placental invasion positive < 0: placental invasion negative
Grade of lacunae	G0,1: 0 G2: 1 G3: 2
Bridging vessels	Absent: 0 Present: 1
PI (uterine artery)	>0.685: 0 ≤0.685: 1
Myometrial thickness	>1.45mm: 0 ≤1.45mm: 1
number of prior cesarean delivery	<2: 0



	≥2: 1
Location of placenta previa	Posterior and/or lateral: 0 Anterior: 1
Type of placenta previa	Partial and/or low lying: 0 Complete: 1
Maternal age	<30: 0 ≥30: 1
Severe bleeding before 34 wk	Absent: 0 Present: 1
Type of previous deliveries	Normal: 0 Cesarean: 1 Normal + cesarean: 2
Parity	<3: 0 ≥3: 1
Abortion	Absent: 0 Present: 1

The equation was significant ( $p < .000$ ) dependent on Wilks' Lambda test, The overall accuracy, sensitivity, specificity, and positive and negative values of PAE were 91%, 100%, 89%, 59.1%, 100%, respectively.

## DISCUSSION

This study investigated screening factors that can effectively predict placenta accreta in a large population of pregnant women.

First, our study findings showed that the the ultrasound parameters of myometrial thickness <1.45mm, lacunar spaces especially G3, presence of bridging vessels, and mean uterine artery PI <0.685 was highly predictive of placental invasion among pregnancies at increased risk. Second, placenta accreta was more frequently found in cases of placenta previa totalis than other types of previa. Third, both ultrasound measurements and maternal characteristics, such as previous cesarean delivery ≥2, parity ≥3, abortion history, and age ≥30 years, severe bleeding before 34wk, and type of prior delivery (combination between normal and cesarean) were significant predictive factors of placenta accreta.

The application of the PAE in clinical practice may be helpful in the antenatal diagnosis of MAP and seems to be a key factor in reducing maternal and fetal morbidity and mortality, by allowing multidisciplinary counseling, providing reassurance to a woman who desires future fertility, and planning and timing of delivery. During the antenatal period, care is taken to increase hemoglobin levels by administration of appropriate medication and to evaluate the patient for any potential obstetric complications. Surgery is planned with an experienced surgeon, anesthetic and perinatal intensive care team. In addition, an adequate number of blood units are made available in the operating room. This multitask approach can only be achieved if early detection of such a potentially life-threatening obstetric disorder is achieved.

Also, instead of using each ultrasound variable individually, our study establishes an equation modeling for a standardized ultrasound evaluation of all patients at risk for morbidly adherent placenta that can be universally adopted.

Assigning the PAE in clinical practice may be helpful in interpreting these various sonographic variables in light of the patient's history. As an example, if a pregnant 37 years at 33 gestational week with severe vaginal bleeding, who has had 3 prior normal deliveries, then 4 prior cesarean deliveries, with 2 previous D&C for abortions, is found to have an anterior complete placenta previa with grade-3 lacunae, smallest myometrial thickness of 0.5 mm, bridging vessels present, and mean PI of 0.56. This would result in a PAE +3.08 (>0). Her placental invasion is positive with accuracy 91% , with a

sensitivity of 100%, specificity of 89%, and PPV and NPV of 59.1% and 100%, respectively. Conversely, a pregnant 25 years at 38 gestational week without vaginal bleeding, who has had 2 prior normal deliveries, then 1 prior cesarean deliverie, without abortions, is found to have an lateral partial placenta previa with grade-0 lacunae, smallest myometrial thickness of 1.5 mm, bridging vessels absent, and mean PI of 0.97. would have a PAE of -1.421 (<0), and her placental invasion is negative. Depending on availability of local resources and multidisciplinary care, results from our equation could thus be used for counseling and assist with referral decisions.

Previous studies have also proposed a standardized evaluation of women at risk for placental invasion.

Weiniger et al<sup>17</sup> recently reported a series of 92 women with placental invasion and developed a predictive equation from mathematical modeling of clinical and sonographic variables. In that series, ultrasound suspicion of invasion was considered a single variable, rather than based on a scoring system. Weiniger et al<sup>17</sup> found that the combination of placenta previa, number of prior cesarean deliveries, and ultrasound suspicion of invasion was more predictive than ultrasound variables alone, with an area under the receiver operator characteristic curve of 0.85.

Gilboa et al<sup>18</sup>. reported a series of 21 women with placenta percreta that was identified at surgery and proposed a scoring system based on the sonographic findings. Their detection rate of placenta percreta was 63.6%. However, the main goal of their scoring system was to identify patients with Stage 3 MAP and offer a prophylactic pelvic artery catheterization.

Maymon et al<sup>19</sup>, found that the sonographic score derived from the number of Cesarean deliveries, the placental location and lacunae features, obliteration of the uteroplacental demarcation and color Doppler flow assessment was highly predictive of MAP, allowing for antenatal and intrapartum specific management. Although two (0.9%) of the 222 women in the low-probability group had MAP (false negative), only minimal placental adherence was observed intraoperatively. They had both normal intrapartum blood loss and postoperative outcome, and the most effective ultrasound criteria for detection of MAP were a combination of two parameters, the number of placental lacunae and obliteration of the uteroplacental demarcation, which yielded an area under the ROC curve of 0.94 (95% CI, 0.86–1.00).

Rac et al<sup>20</sup>, created a predictive equation for placental invasion based on combining patient characteristics with ultrasound variables that were studied in 88 cases, with an area under the receiver operator characteristic curve of 0.87.

Our study confirms the predictive value of combining patient characteristics with ultrasound variables associated with placental invasion, with an area under the receiver operator characteristic curve of 0.996. and it also acknowledges the interaction between the different variables as they contribute to individual risk.

A strong relationship between lacunar spaces and placental invasion has previously been Described Finberg and Williams<sup>11</sup> found that number and bizarre appearance of lacunar spaces was directly correlated with certainty and severity of morbidly adherent placenta. In a recent systematic review, overall pooled sensitivity and specificity of lacunar spaces from 13 studies was 77% and 95% with an overall diagnostic accuracy of 0.884<sup>21</sup>. A similar relationship has been shown for number of prior cesarean deliveries<sup>22,23,24</sup>. In one of the largest prospective series to date, Silver et al<sup>23</sup> found that in the setting of placenta previa, the risk of accreta was 11%, 40%, and >60% in women with 1, 2, and 3 prior cesarean deliveries, respectively. Other characteristics found to be positively associated with morbidly adherent placenta in our model, although to a lesser degree, include placental location, smallest myometrial thickness, bridging vessels, and uterine artery Doppler vlocimetry. Both retrospective and prospective studies, as well as metaanalyses and systematic reviews, have shown high sensitivities for

each of the above parameters<sup>10,11,12,25,26,27</sup>. In 2000, Twickler et al<sup>25</sup> found that a smallest myometrial thickness <1 mm identified in third-trimester pregnancies at risk for placental invasion was 100% sensitive and 72% specific with a PPV and NPV of 72% and 100%, respectively. Cali et al<sup>28</sup> reported recently that the absence of the uteroplacental demarcation was the most effective sonographic criterion for detection of an invasive placenta, with a negative predictive value of 96.7%. Hypervascularity of the uterine-bladder interface using both 2- and 3-dimensional Doppler ultrasound had the best diagnostic performance in a recent prospective series of women with a prior cesarean delivery and placenta previa. Similarly, D'Antonio et al<sup>21</sup> reported that the presence of bridging vessels identified with color Doppler imaging was the most predictive ultrasound parameter of morbidly adherent placenta, with an overall diagnostic accuracy of 0.95. Hee Young Cho et al<sup>13</sup>, their study showed, First that the mean uterine artery PI was decreased in patients with placenta accreta. Second, placenta accreta was more frequently found in cases of placenta previa totalis than other types of previa. Third, both the uterine artery Doppler velocimetric measurements and maternal characteristics, such as previous cesarean delivery, parity, abortion history, and age, were significant predictive factors of placenta accreta, with an area under the receiver operator characteristic curve of 0.80.

Some limitations of this study should be acknowledged. The main one was the fact that the surgical team was not blinded to the ultrasound findings and the diagnosis of MAP during surgery was made by the surgeons in all cases in which hysterectomy was avoided.

Not all women in our cohort underwent transvaginal imaging. Although no studies have been performed that directly compare the diagnostic accuracy of transabdominal vs transvaginal ultrasound in the setting of suspected placental invasion, transvaginal ultrasound allows for a more complete evaluation of the lower uterine segment and is the current recommended standard of care<sup>10,29,30</sup>. Therefore, inclusion of transabdominal imaging could theoretically affect the predictive value of our model.

Ultrasound findings and uterine artery Doppler velocimetry was performed by different operators during the study period. However, all operators were well-trained experts who fully understood the protocol before starting ultrasound findings and doppler measurements. Therefore, interobserver and intraobserver variability would not have been too great, but a bias between operators may still have existed.

Another marker for predicting placenta accreta is maternal serum  $\alpha$ -fetoprotein, was not included in our model. Zelop et al<sup>31</sup> found that pregnant women with placenta accreta had elevated maternal serum  $\alpha$ -fetoprotein levels due to abnormal placental adherence, resulting in leakage of fetal  $\alpha$ -fetoprotein. Future studies need to evaluate the potential value of maternal biomarkers in screening for placenta accreta based on ultrasound findings and Doppler velocimetric measurements with maternal characteristics.

Despite these limitations, strengths of our study include the size of the cohort, a blinded review process, and use of histologic confirmation of invasion. As a result, our model is designed to identify patients with clinically significant placental invasion requiring cesarean hysterectomy, allowing for adequate antenatal risk assessment. It is helpful for patient counseling and delivery planning with a multidisciplinary team approach, all of which may ultimately improve pregnancy outcome in women at risk of MAP.

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