



Percreta score to differentiate between placenta accreta and placenta percreta with ultrasound and MR imaging

Flore-Anne Pain¹  | Anthony Dohan^{2,3} | Gilles Grange¹ | Louis Marcellin^{1,2} |
Joëlle Uzan-Augui³ | François Goffinet^{1,2} | Philippe Soyer^{2,3} | Vassilis Tsatsaris^{1,2} 

¹Department of Gynecology & Obstetrics, FHU PREMA, Cochin Hospital, Paris, France

²Faculty of Medicine, Université Paris Centre, Paris, France

³Department of Radiology, Cochin Hospital, Paris, France

Correspondence

Flore-Anne Pain, Department of Gynecology & Obstetrics, Hôpital Cochin, 123 boulevard de Port Royal 75014 Paris, France.

Email: flore.anne.pain@gmail.com

Abstract

Introduction: The objective of this study was to assess the performance of ultrasound and magnetic resonance imaging (MRI) features in helping to classify the type of placenta accreta spectrum (PAS; accreta/increta vs percreta), alone or combined in a predictive score.

Material and Methods: We conducted a retrospective study in 82 pregnant women with PAS who underwent ultrasound and MRI examination of the pelvis before delivery (from an initial cohort of 185 women with PAS). We estimated the sensitivity, specificity and accuracy of MRI and ultrasound in the diagnosis of the type of PAS. We analyzed cesarean and imaging features using univariable logistic regression analysis. We constructed a nomogram to predict the risk of placenta percreta and validated it with bootstrap resampling, then used receiver operating characteristic curves to assess the performance of the model in distinguishing between placenta percreta and placenta accreta/increta.

Results: Among the 82 patients, 29 (35%) had placenta accreta/increta and 53 (65%) had placenta percreta. The best features to discriminate between placenta accreta/increta and placenta percreta with ultrasound were increased vascularization at the uterine serosa-bladder wall interface (odds ratio [OR] 7.93; 95% confidence interval [CI] 2.78–24.99; $p < 0.01$) and the number of lacunae without a hyperechogenic halo (OR 1.36; 95% CI 1.14–1.67; $p = 0.012$). Concerning MRI markers, heterogeneous placenta (OR 12.89; 95% CI 3.05–89.16; $p = 0.002$), dark intraplacental bands (OR 12.89; 95% CI 3.05–89.16; $p = 0.002$) and bladder wall interruption (OR 15.89; 95% CI 4.78–73.33; $p < 0.001$) had a higher OR in discriminating placenta accreta/increta from placenta percreta. The nomogram yielded areas under the curve of 0.841 (95% CI 0.754–0.927) and 0.856 (95% CI 0.767–0.945), after bootstrap resampling, for the accurate prediction of placenta percreta.

Abbreviations: AUC, area under the receiver operating characteristic curve; CI, confidence interval; MRI, magnetic resonance imaging; OR, odds ratio; PAS, placenta accreta spectrum; SD, standard deviation; ROC, receiver operating characteristic.

This is an open access article under the terms of the [Creative Commons Attribution-NonCommercial](https://creativecommons.org/licenses/by-nc/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

© 2022 The Authors. *Acta Obstetrica et Gynecologica Scandinavica* published by John Wiley & Sons Ltd on behalf of Nordic Federation of Societies of Obstetrics and Gynecology (NFOG).

Conclusions: The nomogram we developed to predict the risk of placenta percreta among patients with PAS had good discriminative capabilities. This performance and its impact on maternal morbidity should be confirmed by future prospective studies.

KEYWORDS

abnormal placentation, magnetic resonance imaging, placenta accreta, placenta accreta spectrum, placenta increta, placenta percreta, ultrasound

1 | INTRODUCTION

Placenta accreta spectrum (PAS) disorder is clinically diagnosed when the placenta cannot be separated from the uterus after delivery.¹ This abnormal attachment of the placenta to the myometrium occurs when a defect of the decidua basalis allows the chorionic villi to invade the myometrium.² Women with previous cesarean section are at a seven-fold higher risk of subsequent PAS.³ Population-based studies have shown a substantial increase in the incidence of PAS, which now appears to affect 1.7–4.6 per 10000 deliveries,⁴ presumably due to the rising use of cesarean section during the last 30 years.⁵

PAS disorder is responsible for adverse maternal outcomes at delivery, mainly due to severe postpartum hemorrhage, and remains the leading cause of peripartum hysterectomy in Western countries.⁶ Placenta percreta is associated with substantially increased maternal morbidity compared with placenta accreta/increta.⁷ Accurate prenatal diagnosis and identification of the type of PAS allows optimal obstetric management so delivery in a center with expertise in surgical management of PAS can be planned and surgical complications reduced.^{8–10}

Ultrasound and magnetic resonance imaging (MRI) are mainly used to diagnose PAS disorder, but the accuracy of these two imaging techniques has varied substantially between studies.¹¹ Many studies have evaluated the diagnostic performances of MRI and ultrasound for the prenatal diagnosis of PAS disorder, with sensitivities ranging between 31% and 91% for ultrasound and between 54% and 97% for MRI.¹² Despite an extensive literature on various PAS markers, inconsistencies persist.¹³ Moreover, the American College of Obstetricians and Gynecologists considers it unclear whether the use of MRI improves the diagnosis of PAS.

In patients with a prenatal diagnosis of PAS, the distinction between placenta accreta (International Federation of Gynaecology and Obstetrics [FIGO] grade 1), increta (FIGO grade 2) and percreta (FIGO grade 3) is of great importance when preparing for delivery. No studies have demonstrated the diagnostic value of combining ultrasound and MRI for the diagnosis of the type of PAS. A precise antenatal diagnosis of the grade of PAS should improve maternal prognosis.

The aim of this study was therefore to assess the performance of ultrasound and MRI features in helping to classify the type of PAS disorder (accreta/increta vs percreta), alone or combined in a predictive score.

Key message

Ultrasound and magnetic resonance imaging combined may improve the diagnosis of placenta percreta among patients with a placenta accreta spectrum.

2 | MATERIAL AND METHODS

2.1 | Patients

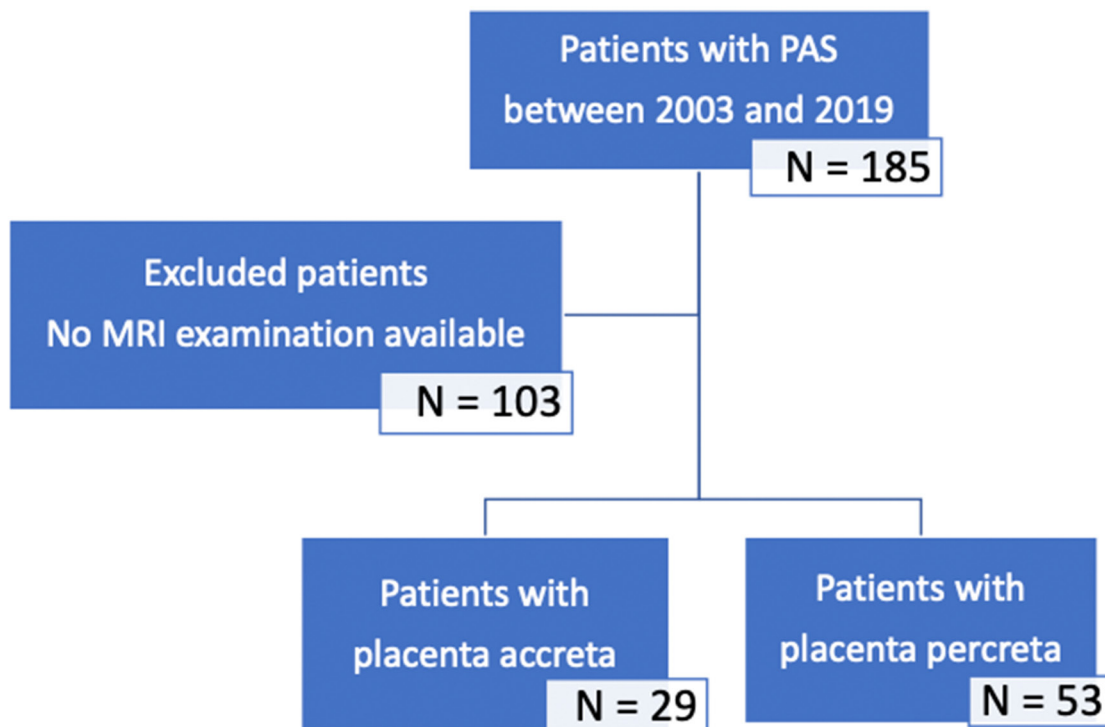
We queried the database of the Department of Obstetrics of our institution to identify all women with PAS disorder who delivered between January 2003 and December 2018. This initial search retrieved 185 women. We included all women with PAS after 20 weeks of gestational age followed up in our center with available prenatal evaluation of the placenta by ultrasound and pelvic MRI and excluded those who did not undergo pelvic MRI and ultrasound and those whose imaging examinations were not available for review. A total of 103 women were excluded because we had no access to pelvic MRI, 89 had placenta accreta/increta and 14 had placenta percreta. [Figure 1a](#) shows the flow chart of the study. [Figure 1b](#) shows the study timeline. Supporting Information Appendix [S1](#) shows the distribution of PAS in the respective years during the study period.

The study coordinator (F-A.P., a fifth-year resident in obstetrics) reviewed the medical files of all included patients and collected data, including maternal history, age at the time of delivery, body mass index, gravidity, parity, number of previous cesarean sections, previous uterine surgery, previous dilatation and curettage and previous PAS disorder.

2.2 | Definition of PAS

PAS was confirmed histologically or clinically, depending on the type of management at birth. For women who underwent hysterectomy, placenta accreta/increta was histologically diagnosed when placental villi had invaded the myometrium without reaching the uterine serosa. For women who received conservative management, placenta accreta was clinically diagnosed during delivery when no (total or partial) cleavage plane was found between the placenta and the uterus during manual removal.¹⁴ We classified PAS using the FIGO classification¹⁵: placenta accreta was classed as grade 1, placenta increta as grade 2 and placenta percreta as grade 3.

(A)



(B) PAS = Placenta accreta spectrum; MRI = Magnetic resonance imaging

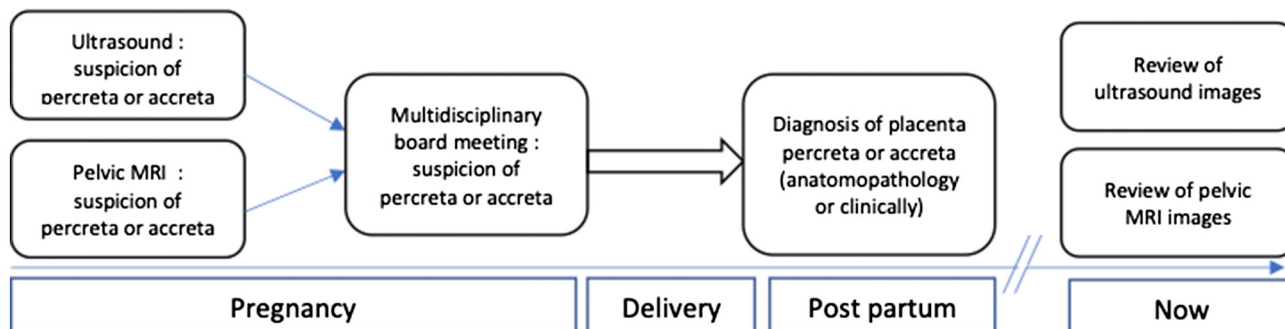


FIGURE 1 Study (A) flow chart and (B) timeline. MRI, magnetic resonance imaging; PAS, placenta accreta spectrum.

The diagnosis of placenta percreta (grade 3) required, in addition to the criteria for PAS, histopathological confirmation that placental villi had invaded the myometrium, reached the uterine serosa, and might have invaded adjacent organs for women who underwent hysterectomy. For women for whom conservative management was successful during cesarean delivery not requiring hysterectomy, clinical observation of gross invasion of the uterine serosa or adjacent organs was necessary.¹⁶ The surgical description was always made by a senior surgeon.

For the purpose of this study, women with placenta accreta (FIGO grade 1) or placenta increta (FIGO grade 2) were included in the accreta/increta group (less severe cases) and those with placenta percreta (FIGO grade 3) in the percreta group (the most severe cases). Combining placenta accreta with placenta increta in the same group is justified because these placentae have similar prognoses and surgical management.

2.3 | Image analysis

All examinations were performed during the third trimester. The mean \pm standard deviation (SD) gestational age was 32 ± 3.09 weeks (range 31.4–32.7) for ultrasound and 32.8 ± 3.02 weeks (range 32.2–33.5) for MRI.

For ultrasound and MRI, the observers were asked to specify the type of PAS disorder. They applied the standard diagnostic criteria as previously reported.¹⁷

2.3.1 | Ultrasound image analysis

For each patient, a report was written at the end of the ultrasound examination, and the conclusion mentioned whether placentation was considered accreta/increta or percreta.

For the purpose of this study, all ultrasound examinations were reviewed retrospectively by an experienced obstetrician (G.G., with 30 years of experience in obstetric imaging) blinded to PAS grade, maternal outcome, original imaging reports and results of MRI examinations. The following sonographic features were analyzed: placental localization, loss of the normal retroplacental clear space, bulge in the bladder, disruption of the hyperechogenic uterine serosa/bladder wall interface, number of intraplacental lacunae with and without a hyperechogenic halo, irregular bladder posterior wall and calcification of the placenta and of suspicious areas.¹⁸ Additionally, several features at Doppler ultrasound were searched for, including increased vascularization at the maternal bed of the placenta, increased vascularization at the uterine serosa–bladder wall interface, vascularization perpendicular to the uterine wall and high-speed vascularization into intraplacental lacunae (i.e., blood flow >15 cm/s)¹⁹ (Supporting Information Figures S1, S2, S3).

2.3.2 | MRI analysis

For each patient, a report was written at the end of the MRI examination, and the conclusion mentioned whether placentation was considered accreta/increta or percreta.

For the purpose of this study, all MRI examinations were reviewed retrospectively by two experienced radiologists (P.S. and J.U.-A., with 25 years of experience in placental imaging) who were both blinded to PAS grade, maternal outcome, results of ultrasound examinations and original imaging reports. MRI examinations were analyzed for the presence of several findings, including heterogeneous placenta, placental bulge in the bladder, dark intraplacental bands on T2-weighted images, intraplacental lacunae, perpendicular vessels at the maternal face of the placenta, placental ischemic infarction, hemorrhagic reshuffle, loss of retroplacental dark zone, myometrial thinning, bladder wall interruption, focal exophytic mass and abnormal vascularization of the placental bed^{20,21} (Supporting Information Figures S1, S2, S3).

2.4 | Multidisciplinary prenatal board meeting for PAS grading

The management of each patient was individually discussed prenatally during the multidisciplinary board meeting of radiologists, obstetricians and surgeons. Clinical data for each individual patient, in combination with the results of imaging examinations, were reviewed during the multidisciplinary board meeting to establish the optimal medical management for the delivery. During that meeting, PAS was graded as accreta/increta or percreta. The conclusion of the multidisciplinary prenatal board (PAS grade) defined the surgical strategy at delivery.

2.5 | Data analysis

Statistical analyses were performed using R (version 4.1.1, R Project) software. Continuous variables were expressed as mean ± SD and

range. Qualitative variables were expressed as raw numbers, proportions and percentages. Differences in continuous variables between women with placenta percreta and those with placenta accreta/increta were searched for using the Wilcoxon–Mann–Whitney test or Student's *t* test when appropriate. Associations between categorical variables were searched for using the chi-squared (χ^2) test or Fisher's exact test when appropriate. The discriminatory capability of each prenatal evaluation (ultrasound, MRI and multidisciplinary board meeting) was assessed using receiver operating characteristics curve (ROC) analysis with calculation of the area under the ROC (AUC).

For continuous variables, the assumption of linearity was verified. Qualitative variables were then entered into univariable analysis with a conditional logistic regression model to identify variables associated with placenta percreta at ultrasound and MRI. The exact method was used when there was either a complete or a quasi-complete separation of data. Multivariable analysis was performed using a logistic regression model with forward stepwise selection of covariables. Correlations between all variables were searched for. When two variables were strongly correlated (i.e., $r > 0.6$), only one was included in the multivariable model. In addition, considering the high number of variables, variables were selected for the multivariable model after the Bonferroni correction was applied (0.05/22). Statistically significant binary variables found at univariable analysis ($p < 0.0022$) were then entered into the multivariable model.

A continuous score for placenta percreta (percreta score) was created based on the final multivariable model via a linear combination of selected features that were weighted by their respective coefficients and further presented as a nomogram. In addition, the nomogram was subjected to 1000 bootstrap resamples for internal validation to assess its accuracy. The discriminatory capability of the score was evaluated using ROC analysis with calculation of the AUC. AUCs (ultrasound, MRI, multidisciplinary board meeting, percreta score) were compared using the DeLong test.

2.6 | Ethical approval

This study was approved by the review board of our institution (CLEP N° AAA-2022-08004) on January 22, 2022.

3 | RESULTS

3.1 | Patients

The study population included 82 women, with a mean ± SD age of 34.7 ± 1.4 years (range 20–43). Of these, 53 (65%) were in the percreta group and 29 (35%) were in the accreta/increta group (Figure 1). The final diagnosis of PAS grade was established using the results of histopathological analysis after hysterectomy in 67/82 patients (82%) and by the analysis of the surgical report made during cesarean section in 15/82 patients (18%): seven had placenta accreta/increta and

eight had placenta percreta. Supporting Information Appendix S2 shows the differences between the intraoperative grading and the histopathological results among the 67 patients who underwent a hysterectomy. Clinical characteristics and histopathological data are described in Table 1. The maternal morbidity composite score previously described is given in Supporting Information Appendix S3.

3.2 | Accuracy of ultrasound and MRI in the prenatal diagnosis of the type of PAS

In total, 71 (87%) patients had a low inserted placenta and 71 (87%) had an anterior placenta. Prenatal PAS classification was correct in 53 (65%) patients with ultrasound and 56 (68%) patients with MRI, with no significant differences between the two techniques ($p = 0.60$). After the multidisciplinary board meeting, 68 (83%) patients had the appropriate PAS prenatal classification using the results of both imaging examinations (Table 2).

There was no difference in sensitivity for the diagnosis of placenta percreta between MRI used alone (62%), ultrasound used alone (55%) and the conclusion of the multidisciplinary board meeting (66%) ($p = 0.46$) (Table 2). There was no statistical difference between the AUC of ultrasound and the AUC of MRI ($p = 0.72$).

3.3 | Ultrasound features

The distributions of the various ultrasound features among women in the percreta group and those in the accreta/increta group are given in Table 3. Among the 12 ultrasound features that were studied, nine were significantly associated with the diagnosis of placenta percreta. Those in favor of placenta percreta were loss of the normal retroplacental clear space ($p < 0.01$), bulge in the bladder ($p < 0.01$), disruption of the hyperechogenic uterine serosa-bladder wall interface ($p < 0.01$), intraplacental lacunae without a hyperechogenic halo ($p = 0.01$), irregular bladder wall ($p = 0.01$), increased vascularization under the placenta ($p < 0.01$) and increased vascularization at the uterine serosa-bladder wall interface ($p < 0.01$). Intraplacental lacunae with a hyperechogenic halo ($p < 0.01$) and calcification of the placenta ($p = 0.02$) were associated with placenta accreta/increta.

Loss of the normal retroplacental clear space had the highest sensitivity (51/53; 96%; 95% confidence interval [CI] 87–100) but the lowest specificity (51/53; 24%; 95% CI 10–44) for the diagnosis of placenta percreta.

3.4 | MRI features

The distributions of the various pelvic MRI features among women with placenta percreta and those with placenta accreta/increta are given in Table 4. Myometrial thinning was excluded because

TABLE 1 Demographic and obstetric characteristics of the study population

	Percreta (N = 53)	Accreta (N = 29)	p-value
Age, (year)	34.7 ± 4.9 (20–44)	34.3 ± 4.7 (29–41)	0.68
BMI, (kg/m ²)	25.9 ± 5.6 (19–46)	26.2 ± 5.2 (18–44)	0.87
Ethnic origin			0.30
Caucasian	24 (45.3)	13 (44.8)	
North African	10 (18.9)	3 (10.3)	
Sub-Saharan African	15 (28.3)	7 (24.1)	
Other	4 (7.5)	6 (20.7)	
Referral from another facility	45 (84.9)	21 (72.4)	0.17
Gestational age at transfer, (week), median (Q1–Q3)	30 (28–31)	32 (30–34)	0.13
Twin pregnancy, n (%)	4 (9.8)	1 (4.3)	0.44
Gravidity			0.32
1	2 (3.8)	2 (6.9)	
2	8 (15.1)	8 (27.6)	
≥3	43 (81.1)	19 (65.5)	
Parity			0.27
Null	0 (0)	3 (10.4)	
1	9 (16.9)	6 (20.7)	
≥2	44 (83.1)	20 (68.9)	
Previous cesarean section			0.12
Null	1 (1.9)	4 (13.8)	
1	13 (24.5)	8 (27.6)	
2	20 (37.7)	11 (37.9)	
≥3	19 (35.8)	6 (20.7)	
At least one previous cesarean section	52 (98)	25 (86.2)	0.05
Previous uterine surgery			
Myomectomy	0 (0)	1 (4.3)	0.35
Operative hysteroscopy	3 (5.7)	2 (6.9)	0.58
Previous dilatation and curettage	23 (43.4)	11 (37.9)	0.63
Previous placenta accreta	1 (1.9)	1 (3.4)	0.58

Note: Data are presented as N (%) or mean ± standard deviation (range) unless otherwise indicated.

Abbreviation: BMI, body mass index.

this feature was present on all MRI examinations. Among the 11 MRI features studied, six were significantly associated with the diagnosis of placenta percreta: heterogeneous placenta ($p = 0.001$), dark intraplacental bands ($p = 0.001$), presence of intraplacental

TABLE 2 Diagnostic performances of ultrasound and MRI for the diagnosis of placenta percreta

	Sensitivity	Specificity	LR+	LR-	DOR	AUC
Ultrasound	55 (40–68)	83 (64–94)	2.98 (1.35–6.59)	0.56 (0.40–0.80)	5.36 (1.84–15.62)	0.69 (0.59–0.79)
MRI	62 (48–75)	79 (60–92)	2.86 (1.41–5.83)	0.49 (0.33–0.72)	5.90 (2.11–16.51)	0.71 (0.61–0.81)
Multidisciplinary board meeting	66 (52–78)	76 (56–90)	2.63 (1.37–5.03)	0.46 (0.30–0.70)	5.76 (2.12–15.64)	0.72 (0.62–0.82)

Note: Data are presented as % (95% confidence interval).

Abbreviations: AUC, area under the curve; DOR, diagnostic odds ratio; LR+, positive likelihood ratio; LR-, negative likelihood ratio; MRI, magnetic resonance imaging.

lacunae ($p = 0.045$), bladder wall interruption ($p < 0.001$), focal exophytic mass ($p = 0.009$) and abnormal vascularization bed ($p = 0.011$).

Loss of retroplacental dark zone had the highest sensitivity (51/53; 98%; 95% CI 90–100) but the lowest specificity (51/53; 14%; 95% CI 4–32) for the diagnosis of placenta percreta. Presence of placental ischemic infarction had the best specificity, but this finding was present in only three patients.

3.5 | Differentiation between placenta accreta/increta and placenta percreta

Table 5 shows the odds ratio [OR] of each imaging feature. The ultrasound features with the highest OR in discriminating between placenta accreta/increta and placenta percreta were the increased vascularization at the uterine serosa–bladder wall interface (OR 7.93; 95% CI 2.78–24.99; $p < 0.01$) and the number of lacunae without a hyperechogenic halo (OR 1.35; 95% CI 1.14–1.67; $p = 0.012$). With MRI, heterogeneous placenta (OR 12.89; 95% CI 3.05–89.16; $p = 0.002$), dark intraplacental bands (OR 12.89; 95% CI 3.05–89.16; $p = 0.002$) and bladder wall interruption (OR 15.89; 95% CI 4.78–73.33; $p < 0.001$) had the highest OR in discriminating between placenta accreta/increta and placenta percreta.

3.6 | Predictive nomogram for the diagnosis of placenta percreta

We constructed a nomogram using the four significant risk factors for predicting placenta percreta with $p < 0.002$ (Figure 2). A total score was calculated using two ultrasound features (number of intraplacental lacunae without a hyperechogenic halo and increased vascularization at the uterine serosa–bladder wall interface) and two MRI features (heterogeneous placenta and dark intraplacental bands). The value of each of these variables was given a score on the point scale axis. A total score was calculated by adding each single score. For each individual patient, the probability of placenta percreta was estimated by projecting the total score to the lower total point scale. The nomogram yielded an AUC of 0.841 (95% CI

0.754–0.927) for the diagnosis of placenta percreta (Figure 3). After internal validation by 1000 bootstrap resampling, the nomogram yielded a corrected AUC of 0.856 (95% CI 0.767–0.945) for the diagnosis of placenta percreta.

The percreta score nomogram yielded a greater AUC than ultrasound (AUC 0.687; 95% CI 0.590–0.785), MRI (AUC 0.708; 95% CI 0.608–0.808) and the prenatal multidisciplinary board meeting (AUC 0.719; 95% CI 0.617–0.820) ($p = 0.008$, $p = 0.029$ and $p = 0.048$, respectively).

Supporting Information Appendix S4 uses an example to explain how to use the nomogram. Supporting Information Appendix S5 is a flow diagram of nomogram accuracy.

4 | DISCUSSION

This retrospective study involving 82 patients with PAS who underwent pelvic ultrasound and MRI antenatally confirmed the complementarity of both imaging techniques in diagnosing the grade of PAS and the need for an experienced multidisciplinary team (radiologist and obstetrician) to establish the correct diagnosis.

The results of our study confirmed that the depth of myometrial invasion increased with the number of prior cesarean sections. They also confirmed the importance of ultrasound features such as increased vascularization at the uterine serosa–bladder wall interface ($p < 0.001$) and the number of lacunae without a hyperechogenic halo ($p = 0.002$). In addition, calcifications of the suspected area and the presence of intraplacental lacunae with a hyperechogenic halo on ultrasound were two ultrasound features that were associated with a minimal depth invasion. These two features could represent the normal development of the placenta because they can be seen in normal placentation. The results of our study also illustrate the importance of intraplacental dark bands ($p = 0.002$) and heterogeneous placenta ($p = 0.002$) on MRI for the differential diagnosis of placenta percreta vs placenta accreta/increta.

With all those features, it is difficult to determine a threshold at which the diagnosis of placenta percreta can be considered.²² In such situations, the nomogram that we built can help to clarify easily which are the most important features and to give a probability of placenta percreta.

TABLE 3 Diagnostic performances of individual ultrasound features for the diagnosis of placenta percreta

Ultrasound feature	N (%)	Accreta (FP) (%)	Percreta (TP) (%)	p-value	Sensitivity	Specificity	LR+	LR-	DOR
Loss of normal retroplacental clear space	82 (100)	22 (76)	51 (96)	<0.01	96 (87–100)	24 (10–44)	1.27 (1.03–1.58)	0.19 (0.05–0.72)	6.87 (1.51–31.23)
Bulge in bladder	81 (99)	8 (28)	32 (62)	<0.01	62 (47–75)	72 (53–87)	2.16 (1.18–3.98)	0.54 (0.36–0.81)	4.01 (1.52–10.55)
Disruption of hyperechogenic uterine serosa-bladder wall interface	81 (99)	2 (7)	17 (32)	<0.01	33 (20–47)	93 (77–99)	3.96 (1.13–13.79)	0.73 (0.59–0.91)	5.42 (1.32–22.34)
Intraplacental lacunae without hyperechogenic halo	82 (100)	19 (66)	47 (89)	0.01	89 (77–96)	34 (18–54)	1.35 (1.02–1.79)	0.34 (0.14–0.82)	3.94 (1.30–11.95)
Intraplacental lacunae with hyperechogenic halo	75 (92)	15 (60)	13 (27)	<0.01	27 (15–42)	40 (21–31)	0.46 (0.27–0.80)	1.79 (1.09–2.95)	0.26 (0.09–0.70)
Irregular bladder wall	81 (99)	2 (7)	16 (31)	0.01	31 (19–45)	93 (77–99)	3.73 (1.07–13.07)	0.75 (0.61–0.93)	4.97 (1.20–20.56)
Calcification of placenta	78 (95)	5 (19)	2 (4)	0.02	4 (0–13)	81 (61–93)	0.23 (0.06–0.96)	1.19 (0.98–1.46)	0.19 (0.04–0.94)
Calcification of suspected area	76 (93)	1 (4)	1 (2)	0.6	2 (0–0.11)	96 (80–100)	0.53 (0.06–4.85)	1.03 (0.93–1.14)	0.51 (0.05–5.21)
Increased vascularization under placenta	77 (94)	16 (61)	45 (88)	<0.01	88 (76–96)	38 (20–59)	1.43 (1.04–1.97)	0.32 (0.14–0.76)	4.46 (1.44–13.78)
Increased vascularization at uterine serosa-bladder wall interface	74 (90)	7 (28)	37 (76)	<0.01	76 (61–87)	72 (51–88)	2.6 (1.39–4.86)	0.35 (0.21–0.60)	7.4 (2.56–21.42)
Vascularization perpendicular to uterine wall	64 (78)	18 (82)	32 (76)	0.6	76 (61–87)	72 (51–88)	0.94 (0.72–1.22)	1.25 (0.47–3.33)	0.75 (0.22–2.61)
High-speed vascularization (>15 cm/s)	53 (64)	13 (60)	18 (46)	0.45	55 (36–72)	35 (15–59)	0.85 (0.54–1.32)	1.27 (0.65–2.52)	0.66 (0.22–2.03)

Abbreviations: DOR, diagnostic odds ratio; FP, false positive; LR+, positive likelihood ratio; LR-, negative likelihood ratio; TP, true positive. Data are presented as % (95% confidence interval) unless otherwise indicated.

TABLE 4 Diagnostic performances of individual MRI features for the diagnosis of placenta percreta

MRI feature	n (%)	Accreta (FP)	Percreta (TP)	p-value	Sensitivity	Specificity	LR+	LR-	DOR
Heterogeneous placenta	80 (98)	19 (66)	49 (96)	0.001	96 (87-100)	34 (18-54)	1.46 (1.12-1.92)	0.14 (0.04-0.51)	10.66 (2.44-46.62)
Placental bulge	80 (98)	22 (76)	46 (90)	0.161	0.90 (79-97)	24 (10-44)	1.19 (0.95-1.50)	0.42 (0.16-1.16)	2.82 (0.84-9.45)
Dark intraplacental bands	80 (98)	19 (66)	49 (96)	0.001	96 (87-100)	34 (18-54)	1.46 (1.12-1.92)	0.14 (0.04-0.51)	10.66 (2.44-46.62)
Lacunae	80 (98)	12 (41)	33 (67)	0.045	67 (52-80)	59 (39-76)	1.55 (0.97-2.47)	0.61 (0.38-0.98)	2.54 (1.01-6.37)
Perpendicular neovessels	80 (98)	8 (28)	16 (32)	0.875	32 (20-47)	72 (53-87)	1.12 (0.56-2.24)	0.95 (0.71-1.26)	1.18 (0.44-3.15)
Placental ischemic infarction	80 (98)	0 (0)	3 (6)	0.472	6 (1-16)	100 (88-100)	4.04 (0.22-75.55)	0.95 (0.87-1.03)	4.26 (0.21-85.38)
Hemorrhagic reshuffle	80 (98)	3 (10)	15 (30)	0.092	29 (17-44)	90 (73-98)	2.56 (0.88-7.44)	0.80 (0.64-0.99)	3.22 (0.91-11.37)
Loss of retroplacental dark zone	80 (98)	25 (86)	50 (98)	0.105	98 (90-100)	14 (4-32)	1.14 (0.98-1.34)	0.19 (0.03-1.16)	5.94 (0.88-40.05)
Bladder wall interruption	80 (98)	3 (10)	33 (65)	<0.001	65 (50-78)	90 (73-98)	5.52 (2.02-15.09)	0.40 (0.27-0.59)	13.71 (3.92-47.90)
Focal exophytic mass	80 (98)	4 (13)	23 (45)	0.009	45 (31-60)	86 (68-96)	3.01 (1.22-7.43)	0.65 (0.48-0.86)	4.67 (1.49-14.63)
Abnormal vascularization placental bed	80 (98)	13 (45)	38 (75)	0.011	76 (62-87)	55 (63-74)	1.65 (1.07-2.52)	0.47 (0.27-0.83)	3.49 (1.35-9.01)

Note: Data are presented as % (95% confidence interval) unless otherwise indicated.

Abbreviations: DOR, diagnostic odds ratio; FP, false positive; LR+, positive likelihood ratio; LR-, negative likelihood ratio; TP, true positive.

TABLE 5 Odds ratio of each imaging feature for the diagnosis of placenta percreta at univariable analysis

	Univariable analysis		
	Odds ratio	95% CI	p-value
Number of cesareans	1.63	1.02–2.71	0.047
Ultrasound features^a			
Loss of the normal retroplacental clear space	8.11	1.80–57.47	0.013
Bulge in the bladder	4.20	1.61–11.81	0.004
Disruption of the hyperechogenic uterine serosa bladder wall interface	6.56	1.68–43.63	0.017
Intraplacental lacunae without hyperechogenic halo	1.35	1.14–1.67	0.002
Intraplacental lacunae with hyperechogenic halo	0.57	0.36–0.83	0.008
Irregular bladder wall	6.00	1.53–40.00	0.024
Calcification of the placenta	0.17	0.02–0.85	0.042
Calcification of the suspected area	0.51	0.02–13.26	0.639
Increased vascularization at the uterine serosa-bladder wall interface	7.93	2.78–24.99	<0.001
Increased vascularization under the placenta	4.69	1.50–15.83	0.009
Vascularization perpendicular to the uterine wall	0.71	0.17–2.47	0.606
MRI features^b			
Heterogeneous placenta	12.89	3.05–89.16	0.002
Placental bulge	2.93	0.84–10.90	0.093
Dark intraplacental bands	12.89	3.05–89.16	0.002
Lacunae	2.92	1.14–7.73	0.027
Perpendicular neovessels	1.24	0.46–3.51	0.681
Hemorrhagic reshuffle	3.61	1.06–16.74	0.060
Loss of retroplacental dark zone	8.00	1.11–160.97	0.069
Abnormal vascularization of the placental bed	3.9	1.49–10.65	0.006
Focal exophytic mass	5.13	1.69–19.34	0.007
Bladder wall interruption	15.89	4.78–73.33	<0.001

Abbreviations: CI, confidence interval; MRI, magnetic resonance imaging.

^aThe ultrasound feature high-speed vascularization was excluded because we could examine this feature for only 53 patients.

^bTwo MRI features were excluded: myometrial thinning because all the patients had this feature, and ischemic infarction because only three patients, from the percreta group, had this sign.

In our study, combining ultrasound and MRI with the use of a nomogram improved the positive predictive value of the percreta diagnosis. Einerson et al. found that MRI can be misleading regarding the diagnosis of PAS,²³ whereas in our study all women were diagnosed with PAS antenatally, but not always with the actual degree of placental invasion. In contrast, Romeo et al. found that MRI and ultrasound are complementary in diagnosing PAS and predicting the degree of placental invasion.²⁴

Despite the recent characterization of these features and the use of a common terminology,¹⁷ the description of images remains subjective, thus justifying the need for a standardized objective score.²⁵ Several ultrasound features have been reported to identify PAS,²⁶ but there is a lack of organization of these features in predicting the depth of placental involvement. Rac et al. made an index score to predict placental invasion using ultrasound features and the number of prior cesarean sections.²⁷ These researchers used a logistic regression and weighted each feature to create a 9-point scale in which a score of 0 to 9 provided a probability of invasion. In our study, we designed a score combining MRI and ultrasound features to improve the prediction of placenta percreta.

Recently, Clark et al. found that several MRI features were significantly associated with the degree of placental invasion.²⁸ Some significant features included placental bulge (OR 7.4; 95% CI 1.2–45.8), dark intraplacental bands (OR 4.4; 95% CI 1.4–25.8) and placental heterogeneity (OR 5.9; 95% CI 1.4–25.8), which are similar to those found in our study. The outcome in Clark et al. was the need for hysterectomy, but it is commonly acknowledged that the need for hysterectomy in women with PAS is not always related to the depth of invasion of the placenta.

The results of our study should be considered with caution because, from a statistical viewpoint, the population was from only one center, and statistical analyses were conducted on a limited number of patients with a high prevalence of placenta percreta (65%). Also, 89 of the 103 patients excluded because of the absence of MRI had placenta accreta/increta. This could be because MRI was not always performed when PAS did not seem to be percreta on ultrasound. Morel et al. also found a high prevalence of placenta percreta (66%) in their cohort.²⁹ They found only one ultrasound feature associated with placenta percreta, and none of the MRI features were associated with placenta percreta. We could explain this lack of association by the fact that the images were not reviewed, and a lot of data about the presence or absence of the different features were missing.

All our ultrasound images were reviewed by an experienced sonographer, so the operator's experience had an impact on our results. Nevertheless, PAS should be treated in a reference center with an experienced team.

We did not study fetal MRI features such as intraplacental fetal vessels. Bourgioti et al. showed that combining the assessment of intraplacental fetal vessels with other MRI descriptors improved the ability of MRI to help predict PAS and that a vessel diameter of ≥ 3 mm was predictive of placenta percreta (OR 10; 95% CI 1.5–70.4).³⁰

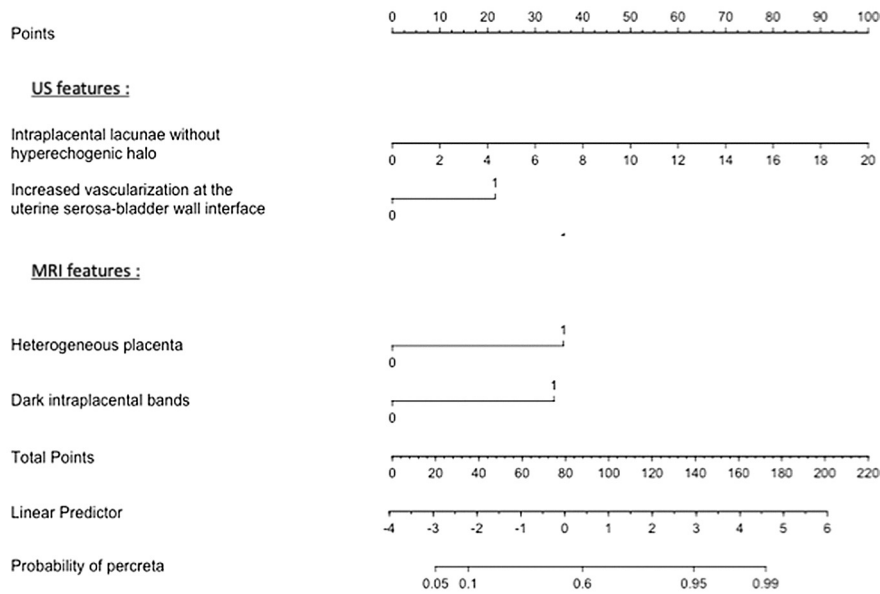


FIGURE 2 Nomogram for the diagnosis of placenta percreta vs placenta accreta/increta. The model used the following equation: $(0.2469005 \times \text{number of intraplacent lacunae without a hyperechogenic halo}) + (1.0661005 \times \text{increased vascularization at the uterine serosa-bladder wall interface}) + (1.7741973 \times \text{heterogeneous placenta}) + (1.6751851 \times \text{dark intraplacent bands}) - 3.9321256$. The final score was obtained using 1 for present and 0 for absent. MRI, magnetic resonance imaging; US, ultrasound.

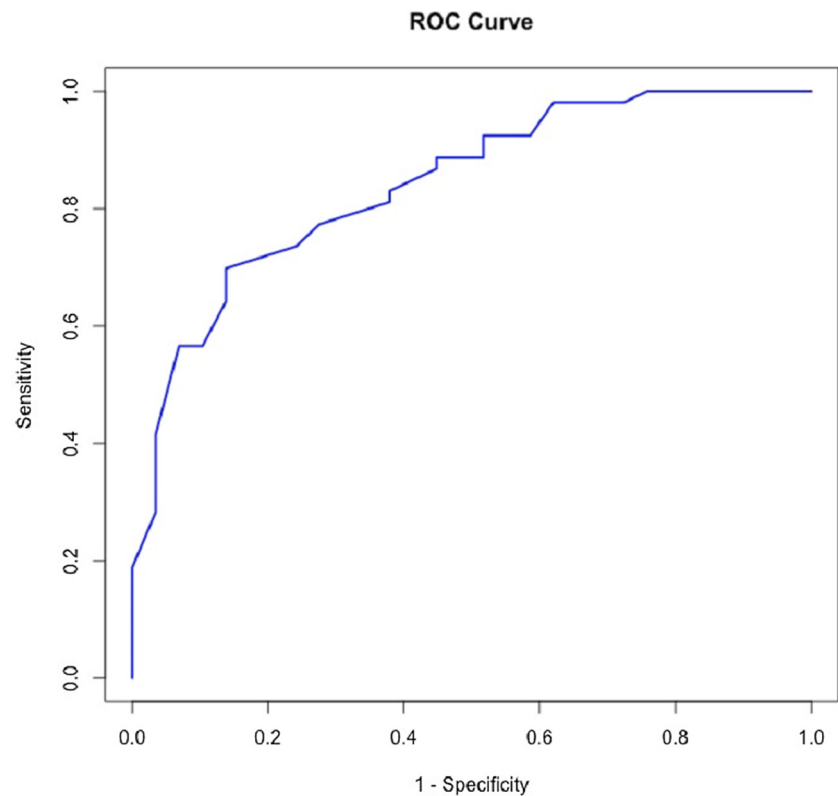


FIGURE 3 Area under the curve of the nomogram: 0.841 (95% confidence interval 0.850–0.981). ROC, receiver operating curve.

5 | CONCLUSION

We developed a nomogram based on both ultrasound and MRI to predict the degree of placental myometrial invasion antenatally. The nomogram yielded a greater AUC for the diagnosis of placenta percreta than ultrasound, MRI or multidisciplinary board meeting individually. Improving the diagnosis of the grade of PAS before delivery can guide clinical management, determine the mode of delivery and decrease the morbidity and mortality of mothers and infants.^{10,31}

AUTHOR CONTRIBUTIONS

FAP: Conceptualization, data curation, formal analysis, statistics, methodology, project administration, writing of original draft, review and editing. VT: Conceptualization, methodology, supervision, writing of original draft, review and editing. LM: Data curation, review and editing. GG: Data curation and ultrasound reading. AD: Formal analysis, statistics, methodology, supervision, review and editing. PS: Methodology, MRI reading, supervision, writing of original draft, review and editing. JUA: MRI reading. FG: review and editing.

CONFLICT OF INTEREST

None.

ORCID

Flore-Anne Pain  <https://orcid.org/0000-0002-1280-1847>

Vassilis Tsatsaris  <https://orcid.org/0000-0002-7650-6660>

REFERENCES

1. Jauniaux E, Burton GJ. Placenta accreta spectrum: a need for more research on its aetiopathogenesis. *BJOG*. 2018;125:1449-1450.
2. Publications Committee. Society for Maternal-Fetal Medicine, Belfort MA. *Placenta Accreta Am J Obstet Gynecol*. 2010;203:430-439.
3. Thurn L, Lindqvist PG, Jakobsson M, et al. Abnormally invasive placenta—prevalence, risk factors and antenatal suspicion: results from a large population-based pregnancy cohort study in the Nordic countries. *BJOG*. 2016;123:1348-1355.
4. Kayem G, Seco A, Beucher G, et al. Clinical profiles of placenta accreta spectrum: the PACCRETA population-based study. *BJOG*. 2021;128:1646-1655.
5. Betrán AP, Ye J, Moller AB, Zhang J, Gülmezoglu AM, Torloni MR. The increasing trend in caesarean section rates: global, regional and National Estimates: 1990-2014. *PLoS One*. 2016;11:e0148343.
6. Soyer P, Barat M, Loffroy R, et al. The role of interventional radiology in the management of abnormally invasive placenta: a systematic review of current evidences. *Quant Imaging Med Surg*. 2020;10:1370-1391.
7. Marcellin L, Delorme P, Bonnet MP, et al. Placenta percreta is associated with more frequent severe maternal morbidity than placenta accreta. *Am J Obstet Gynecol*. 2018;219:193.e1-193.e9.
8. Tikkanen M, Paavonen J, Loukovaara M, Stefanovic V. Antenatal diagnosis of placenta accreta leads to reduced blood loss. *Acta Obstet Gynecol Scand*. 2011;90:1140-1146.
9. Eller AG, Bennett MA, Sharshiner M, et al. Maternal morbidity in cases of placenta accreta managed by a multidisciplinary care team compared with standard obstetric care. *Obstet Gynecol*. 2011;117:331-337.
10. Warshak CR, Ramos GA, Eskander R, et al. Effect of predelivery diagnosis in 99 consecutive cases of placenta accreta. *Obstet Gynecol*. 2010;115:65-69.
11. Barzilay E, Brandt B, Gilboa Y, et al. Comparative analysis of ultrasound and MRI in the diagnosis of placenta accreta spectrum. *J Matern Fetal Neonatal Med*. 2020;12:1-4. doi:10.1080/14767058.2020.1846699
12. Daney de Marcillac F, Molière S, Pinton A, et al. Accuracy of placenta accreta prenatal diagnosis by ultrasound and MRI in a high-risk population. *J Gynecol Obstet Biol Reprod (Paris)*. 2016;45:198-206.
13. Soyer P, Morel O, Tsatsaris V, Bourgioti C, Barat M. Placenta Accreta Spectrum: a continuously evolving challenge for radiologists. *Can Assoc Radiol J*. 2021;72:597-598.
14. Jauniaux E, Bhide A, Kennedy A, et al. FIGO consensus guidelines on placenta accreta spectrum disorders: prenatal diagnosis and screening. *Int J Gynaecol Obstet*. 2018;140:274-280.
15. Jauniaux E, Ayres-de-Campos D, Langhoff-Roos J, Fox KA, Collins S. FIGO placenta Accreta diagnosis and management expert consensus panel. FIGO classification for the clinical diagnosis of placenta accreta spectrum disorders. *Int J Gynecol Obstet*. 2019;146:20-24.
16. Hecht JL, Baergen R, Ernst LM, et al. Classification and reporting guidelines for the pathology diagnosis of placenta accreta spectrum (PAS) disorders: recommendations from an expert panel. *Mod Pathol*. 2020;33:2382-2396.
17. Collins SL, Ashcroft A, Braun T, et al. Proposal for standardized ultrasound descriptors of abnormally invasive placenta (AIP). *Ultrasound Obstet Gynecol*. 2016;47:271-275.
18. Cali G, Forlani F, Lees C, et al. Prenatal ultrasound staging system for placenta accreta spectrum disorders. *Ultrasound Obstet Gynecol*. 2019;53:752-760.
19. Shainker SA, Coleman B, Timor-Tritsch IE, et al. Special report of the Society for Maternal-Fetal Medicine Placenta Accreta Spectrum Ultrasound Marker Task Force: consensus on definition of markers and approach to the ultrasound examination in pregnancies at risk for placenta accreta spectrum. *Am J Obstet Gynecol*. 2021;224:B2-B14.
20. Jha P, Pöder L, Bourgioti C, et al. Society of Abdominal Radiology (SAR) and European Society of Urogenital Radiology (ESUR) joint consensus statement for MR imaging of placenta accreta spectrum disorders. *Eur Radiol*. 2020;30:2604-2615.
21. Morel O, Collins SL, Uzan-Augui J, et al. A proposal for standardized magnetic resonance imaging (MRI) descriptors of abnormally invasive placenta (AIP) – from the international society for AIP. *Diagn Interv Imaging*. 2019;100:319-325.
22. Happe SK, Yule CS, Spong CY, et al. Predicting placenta Accreta Spectrum: validation of the placenta Accreta index. *J Ultrasound Med*. 2021;40:1523-1532.
23. Einerson BD, Rodriguez CE, Kennedy AM, Woodward PJ, Donnelly MA, Silver RM. Magnetic resonance imaging is often misleading when used as an adjunct to ultrasound in the management of placenta accreta spectrum disorders. *Am J Obstet Gynecol*. 2018;218:618.e1-618.e7.
24. Romeo V, Verde F, Sarno L, et al. Prediction of placenta accreta spectrum in patients with placenta previa using clinical risk factors, ultrasound and magnetic resonance imaging findings. *Radiol Med*. 2021;126:1216-1225.
25. Finazzo F, D'antonio F, Masselli G, et al. Interobserver agreement in MRI assessment of severity of placenta accreta spectrum disorders. *Ultrasound Obstet Gynecol*. 2020;55:467-473.
26. Xia H, Ke SC, Qian RR, Lin JG, Li Y, Zhang X. Comparison between abdominal ultrasound and nuclear magnetic resonance imaging detection of placenta accreta in the second and third trimester of pregnancy. *Medicine (Baltimore)*. 2020;99:e17908.
27. Rac MWF, Dashe JS, Wells CE, Moschos E, McIntire DD, Twickler DM. Ultrasound predictors of placental invasion: the placenta Accreta index. *Am J Obstet Gynecol*. 2015;212(343):e1-e7.
28. Clark HR, Ng TW, Khan A, et al. Placenta Accreta Spectrum: correlation of MRI parameters with pathologic and surgical outcomes of high-risk pregnancies. *AJR Am J Roentgenol*. 2020;214:1417-1423.
29. Morel O, van Beekhuizen HJ, Braun T, et al. Performance of antenatal imaging to predict placenta accreta spectrum degree of severity. *Acta Obstet Gynecol Scand*. 2021;100(Suppl 1):21-28.
30. Bourgioti C, Konstantinidou AE, Zafeiropoulou K, et al. Intraplacental fetal vessel diameter may help predict for placental invasiveness in pregnant women at high risk for placenta Accreta Spectrum disorders. *Radiology*. 2021;298:403-412.
31. Bowman ZS, Manuck TA, Eller AG, Simons M, Silver RM. Risk factors for unscheduled delivery in patients with placenta accreta. *Am J Obstet Gynecol*. 2014;210(241):e1-e6.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Pain F-A, Dohan A, Grange G, et al. Percreta score to differentiate between placenta accreta and placenta percreta with ultrasound and MR imaging. *Acta Obstet Gynecol Scand*. 2022;101:1135-1145. doi: [10.1111/aogs.14420](https://doi.org/10.1111/aogs.14420)