Diagnostic accuracy of first-trimester ultrasound in detecting abnormally invasive placenta in high-risk women with placenta previa

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ABSTRACT

Objective *To ascertain the diagnostic accuracy of ultrasound in detecting abnormally invasive placenta (AIP) during the first trimester of pregnancy (11–14 weeks' gestation) in women at risk for this condition.*

Methods *This was a retrospective analysis of data collected prospectively from women at risk for AIP based upon the presence of at least one prior Cesarean section (CS) and/or uterine surgery and placenta previa, who had ultrasound assessment for AIP at the time of the 11–14-week scan. The ultrasound signs explored in the present study were: loss of the clear zone, placental lacunae, bladder wall interruption and uterovesical hypervascularity. The potential of ultrasound and different ultrasound signs to predict the different types of AIP was assessed by computing summary estimates of sensitivity, specificity, diagnostic odds ratio (DOR) and positive (LR+) and negative (LR−) likelihood ratios.*

Results *One hundred and eighty-eight women with placenta previa and at least one previous CS or uterine surgery were included in the study. All the explored ultrasound signs were associated significantly with the occurrence of AIP. Overall, when at least one ultrasound sign was used to make the diagnosis, ultrasound had a sensitivity of 84.3% (95% CI, 74.7–91.4%), specificity of 61.9% (95% CI, 51.9–71.2%), DOR of 8.6 (95% CI, 4.1–19.3), LR+ of 2.2 (95% CI, 1.7–2.9) and LR− of 0.3 (95% CI, 0.1–0.4) in detecting AIP. Using two ultrasound signs to label a case as positive increased the diagnostic accuracy in terms of specificity, although it did not affect sensitivity. Among the different ultrasound signs, loss of the clear zone had a sensitivity of 84.3% (95% CI, 74.7–91.4%) and a specificity of 81.9% (95% CI, 73.2–88.7%) in detecting AIP, while sensitivities for placental lacunae and bladder wall interruption were 78.3% (95% CI, 67.9–86.6%) and 75.9% (95% CI, 65.3–84.6%), respectively, and specificities were 81.0% (95% CI, 72.1–88.0%) and 99.1% (95% CI, 94.8–100.0%), respectively. The optimal combination of sensitivity and specificity was achieved when at least two imaging signs of AIP were used in the diagnostic algorithm.*

Conclusions *AIP can be detected from the first trimester of pregnancy in women at risk for this condition, and ultrasound performed between 11 and 14 weeks' gestation has an overall good diagnostic accuracy for detecting all types of AIP. However, these findings are applicable only to women with placenta previa and prior uterine scar. Copyright © 2018 ISUOG. Published by John Wiley & Sons Ltd.*

INTRODUCTION

The rise in Cesarean-section (CS) rate observed during the last two decades has led to a large increase in the prevalence of abnormally invasive placenta (AIP)[1]. AIP encompasses a spectrum of disorders characterized by various degrees of placental invasion through the myometrium and uterine serosa. It is associated with

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a high burden of maternal morbidities such as severe life-threatening hemorrhage, need for blood transfusion, reoperation and damage to adjacent organs[2–4].

Prenatal diagnosis of AIP is fundamental and it has been reported to improve outcome by allowing preplanned treatment in centers with a high level of surgical expertise[5]. Although the prenatal diagnosis of AIP is commonly achieved during the second or third trimester of pregnancy, there are reports suggesting that signs of AIP are already present in early pregnancy[6].

A recent systematic review exploring the diagnostic performance of first-trimester ultrasound in detecting AIP reported that signs of AIP can be detected in about 90% of women affected by these anomalies who are scanned during the first trimester of pregnancy[6]. Despite this, the small sample size of included studies, heterogeneity in gestational age at assessment and explored ultrasound signs, and inclusion of only cases with confirmed AIP, with subsequent lack of information on specificity, does not allow extrapolation of robust evidence on the actual diagnostic performance of ultrasound in detecting AIP during the first trimester of pregnancy.

The aim of this study was to ascertain the diagnostic accuracy of ultrasound in detecting AIP during the first trimester of pregnancy in women at risk for this condition.

METHODS

This was a retrospective analysis of data collected prospectively from women at risk for AIP who were referred to our center between 2007 and 2017. These women were identified from an electronic database of the fetal medicine unit. Delivery details were retrieved from hospital maternity records, and operative notes were checked for details of operative findings and interventions performed.

Inclusion criteria were women with at least one prior CS and/or uterine surgery and placenta previa who had an ultrasound assessment for AIP at the time of the 11–14-week scan. Repeat assessments were performed in the second and third trimesters of pregnancy. Data regarding the presence of the different ultrasound signs of AIP were entered prospectively at the time of the original examination. Two examiners (G.C., F.D.A.), blinded to pregnancy outcome and pathology reports, analyzed all the stored images independently and labeled them according to the presence of different ultrasound signs suggestive of AIP.

The ultrasound signs explored in the present study (Figure 1) were[7]: (1) loss of the 'clear zone', defined as loss or irregularity of the hypoechoic plane in the myometrium beneath the placental bed; (2) placental lacunae, defined as the presence of numerous (at least three) lacunae, often containing turbulent flow visible on gray-scale or color Doppler ultrasound; (3) bladder wall interruption, defined as loss or interruption of the bright bladder wall (hyperechoic band or 'line' between the uterine serosa and bladder lumen); and (4) uterovesical hypervascularity, defined as a striking amount of color Doppler signal

seen between the myometrium and posterior wall of the bladder, including vessels appearing to extend from the placenta, across the myometrium and beyond the serosa into the bladder or other organs, often running perpendicularly to the myometrium.

Ultrasound assessment was performed transabdominally in all cases, while transvaginal ultrasound was limited to cases with a strong suspicion of AIP, cases in which transabdominal ultrasound did not allow overall good visualization of the bladder–uterine interface and retroplacental space or in cases of posterior placenta. All examinations were performed originally using a GE Voluson 730 or GE Voluson E8 (GE Healthcare Italy, Milan, Italy) or a Samsung WS80A Elite (Samsung Healthcare Italy, Milan, Italy) ultrasound machine, equipped with a 4.0–6.0-MHz curved transabdominal or 5.0–7.0-MHz transvaginal transducer. When using color Doppler ultrasound, the pulse-repetition frequency was initially set at 1.3 kHz, but was later lowered in order to identify the presence of placental lacunar flow.

The final diagnosis of the type of AIP was made after surgery and hysterectomy on the basis of the pathological examination of the removed uterus. Placenta accreta was diagnosed when anchoring placental villi were attached to the myometrium rather than to the decidua, but without completely invading it. Placenta increta was diagnosed when chorionic villi penetrated the myometrium, while placenta percreta was diagnosed when chorionic villi penetrated through the myometrium into the uterine serosa or adjacent organs[4].

We planned a sensitivity analysis according to the depth of placental invasion and the number of prior CSs. For the purpose of this analysis, AIP was divided into two different subgroups: placenta accreta/increta and placenta percreta. STARD (Standards for Reporting of Diagnostic Accuracy Studies) guidelines for studies on diagnostic accuracy were followed[8].

We investigated the potential association between AIP – overall and by degree of invasion (placenta accreta/increta or percreta) – and nine potential predictors, including four ultrasound signs (loss of the clear zone, placental lacunae, bladder wall interruption and uterovesical hypervascularity) and five other maternal/gestational characteristics (mother's age, gestational age at birth, parity, number of previous CSs and previous uterine surgery).

We first evaluated the prevalence of AIP by each potential predictor using standard univariate analysis: the chi-square test for categorical variables and the t-test and Kruskal–Wallis test for normally and non-normally distributed continuous variables, respectively (distribution assessed using the Shapiro–Wilk test). Both number of previous CSs and overall number of detected ultrasound signs (which was computed for each woman) were included in the analyses, both in their original (continuous) form and after dichotomization. The number of previous CSs was split into three dichotomous variables, each including women with one or no, two or three or more CSs; the overall number of ultrasound signs was
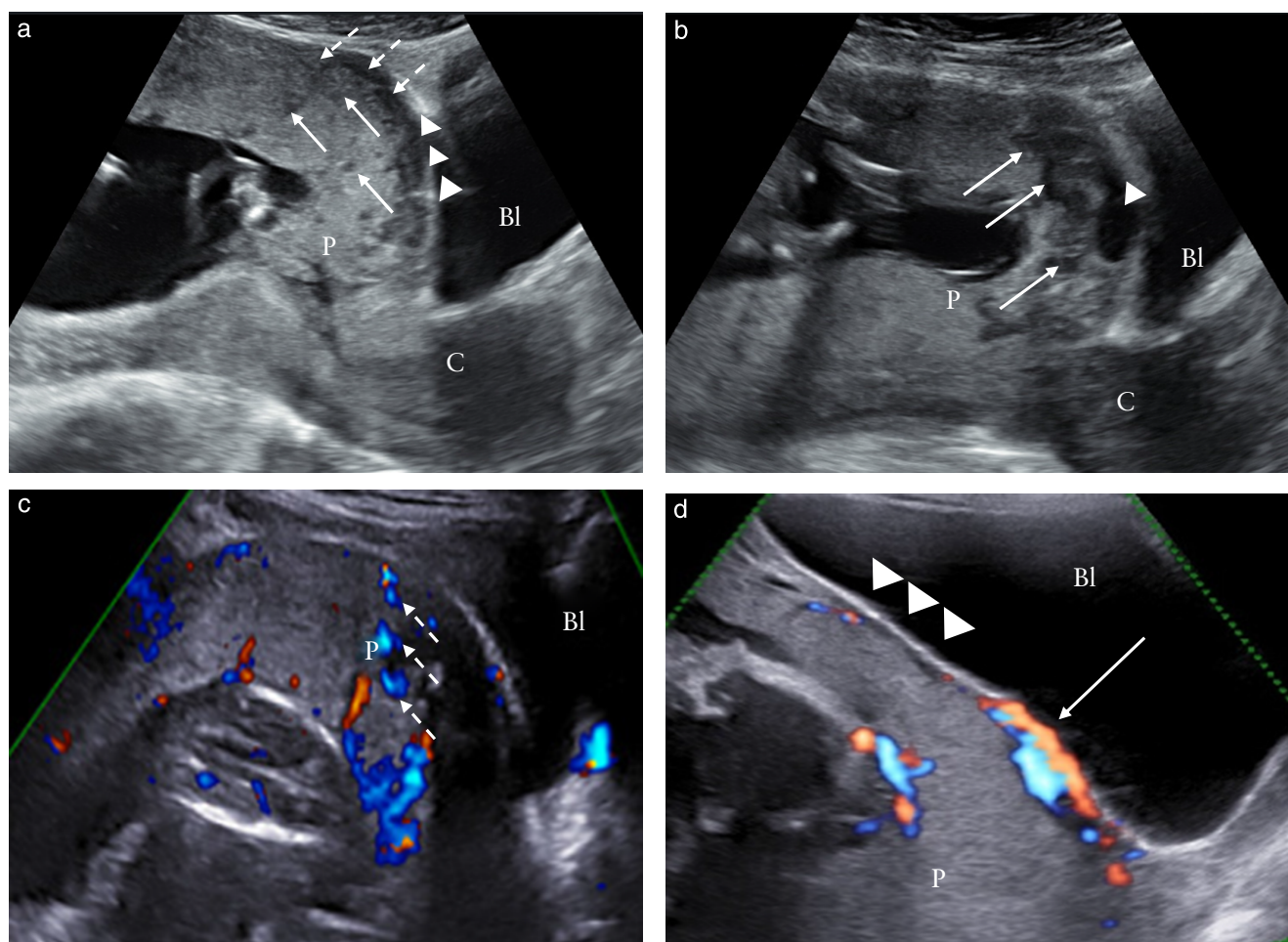
Figure 1 Ultrasound signs of abnormally invasive placenta in first trimester of pregnancy (11–14 weeks' gestation). (a) Transabdominal ultrasound (TAS), showing anterior placenta (P) previa, in which several hypoechoic round areas (placental lacunae) can be detected in placental parenchyma (arrows) and irregularity of hypoechoic plane beneath placental bed (loss of clear zone) is present (dotted arrows), as well as interruption of hyperechoic line between uterine serosa and bladder (Bl) lumen (bladder wall interruption, arrowheads). (b) TAS at 13 weeks, showing placenta implanted above internal cervical os (major previa), in which several placental lacunae (arrows) and interruption of bladder wall can be detected. (c) Color Doppler imaging, showing presence of blood flow within lacunae (dashed arrows). (d) Color Doppler imaging, showing presence of blood flow at level of bladder wall (arrow); irregularity of retroplacental clear zone is also visible (arrowheads). C, cervix.

used to generate four dichotomous variables (women with no, one, two or three or more detected signs).

Stepwise forward logistic regression analysis was then used to identify potential independent predictors of AIP. All covariates were tested for inclusion in the final model, in which only those significant on univariate analysis were retained. To reduce potential overfitting, the overall number of covariates was limited to 1/10 of the successes in all phases of model building. The goodness-of-fit was checked using the Hosmer–Lemeshow test, and the predictive power assessed through C-statistics (area under the receiving–operating characteristics curve). Standard postestimation tests were used to check the final model for validity, performing multicollinearity and influential observation analysis (using standardized residuals, change in Pearson's chi-square and deviance). There were no missing values, thus no missing imputation technique was adopted.

We finally estimated the potential of each ultrasound sign to predict AIP, computing summary estimates of sensitivity, specificity, positive and negative likelihood ratios (LR+ and LR−) and diagnostic odds ratios (DOR). Similarly, we assessed the diagnostic accuracy of the presence of two or ≥ three ultrasound signs in the same woman, and of one, two or ≥ three previous CSs.

Statistical significance was defined as a two-sided P of < 0.05, and analysis was performed using Stata 13.1 (StataCorp, College Station, TX, USA, 2013).

RESULTS

One hundred and eighty-eight women with placenta previa and at least one previous CS or uterine surgery were included in the study. The prevalence of AIP was 44.2% (95% CI, 37.2–51.3%); among the different types of AIP, placenta accreta/increta occurred in 54.2% (95% CI, 44.6–64.5%) while percreta occurred in 45.8% (95% CI, 35.5–56.5%) of cases.

General characteristics of the population analyzed in the study are reported in Table 1. Compared with those

unaffected by AIP, maternal age (34.3 ± 4.2 *vs* 29.6 ± 5.3; *P* = 0.0001), parity (2 (2–3) *vs* 2 (0–2); *P* = 0.0001) and number of previous CSs (2 (1–2) *vs* 2 (0–2); *P* = 0.0006) were higher in affected women, and these differences persisted when the women were stratified according to the severity of placental invasion. On logistic regression analysis, maternal age (OR 1.2 (95% CI, 1.1–1.4)) and number of ultrasound signs detected on the scan (OR 8.4 per 1-unit increase (95% CI, 4.2–17.0 per 1-unit increase)) were associated independently with the occurrence of AIP (Table S1).

Table 2 reports the prevalence and risk of detecting the different ultrasound signs of AIP in women affected, compared with those unaffected, by AIP. When comparing the prevalence of the different ultrasound signs of AIP explored in the present study between the first (11–14 weeks) and the second/third trimesters of pregnancy, loss of the clear zone was detected in 84.3% of cases in the first and in 92.4% in the second/third trimesters of pregnancy (*P* = 0.104), while the corresponding figures for placenta lacunae, bladder wall interruption and uterovesical hypervascularity were

78.3% and 100% (*P* = 0.0001), 75.9% and 93.3% (*P* = 0.0013) and 50.6% and 81.0% (*P* = 0.0001), respectively. There was full agreement in the labeling of all images with regard to the type of ultrasound sign between the original examiner and the two researchers in this study.

Loss of the clear zone was associated with a higher risk of AIP, with an OR of 24.4 (95% CI, 11.3–52.8) (Table 2); likewise, the presence of placental lacunae (OR 15.4 (95% CI, 7.5–31.3)), bladder wall interruption (OR 327.6 (95% CI, 42.9–2501.0)) and uterovesical hypervascularity (OR 216.1 (95% CI, 13.0–3593.3)) were more prevalent in women affected by AIP than in those unaffected by AIP who were scanned during the first trimester of pregnancy. When stratifying the analysis according to the severity of placental invasion, the strength of association between each of the explored ultrasound signs persisted (Table 2). However, in women affected by placenta percreta, there was a higher prevalence of each of the ultrasound signs suggestive of AIP than in controls.

Table 3 reports the diagnostic accuracy of the different ultrasound signs in detecting AIP at the 11–14-week scan.

Table 1 Characteristics of pregnant women at risk for abnormally invasive placenta (AIP), with univariate analyses comparing each potential predictor in affected *vs* unaffected women, overall and according to severity of AIP

Characteristic	Overall sample (n = 188)	No AIP (n = 105)	All AIP (n = 83)	P*	Placenta accreta/ increta (n = 45)	P†	Placenta percreta (n = 38)	P‡
Maternal age (years)	31.7 ± 5.4	29.6 ± 5.3	34.3 ± 4.2	< 0.001	34.5 ± 4.6	< 0.001	34.1 ± 3.7	< 0.001
GA at delivery (weeks)	35.4 ± 2.3	36.3 ± 1.1	34.2 ± 2.9	< 0.001	35.1 ± 1.6	< 0.001	33.3 ± 3.7	< 0.001
Parous	46 (24.5)	22 (21.0)	24 (28.9)	0.234	14 (31.1)	0.212	10 (26.3)	0.502
Previous CS								
≤ 1	75 (39.9)	52 (49.5)	23 (27.7)	0.003	14 (31.1)	0.048	9 (23.7)	0.007
2	71 (37.8)	31 (29.5)	40 (48.2)	0.010	21 (46.7)	0.06	19 (50.0)	0.029
≥ 3	42 (22.3)	22 (21.0)	20 (24.1)	0.745	10 (22.2)	0.832	10 (26.3)	0.502
Previous uterine surgery§	70 (37.2)	70 (66.7)	0 (0.0)	—	0 (0.0)	—	0 (0.0)	—

Data are given as mean ± SD or *n* (%). *P* calculated using chi-square test for categorical variables, and *t*-test and Kruskal–Wallis test for normally and non-normally distributed continuous variables, respectively. *All women diagnosed with AIP *vs* those without AIP. †Women diagnosed with placenta accreta or increta *vs* those without AIP. ‡Women diagnosed with placenta percreta *vs* those without AIP. §Other than Cesarean section (CS). GA, gestational age.

Table 2 Odds ratios (OR) for prediction of abnormally invasive placenta (AIP) for each ultrasound sign explored in present study of 188 high-risk women, overall and according to severity of AIP

AIP subgroup and ultrasound sign	AIP (n (%))	No AIP (n (%))	OR (95% CI)	P
All AIP	n = 83	n = 105		
Loss of clear zone	70 (84.3)	19 (18.1)	24.4 (11.3–52.8)	< 0.0001
Placental lacunae	65 (78.3)	20 (19.0)	15.4 (7.5–31.3)	< 0.0001
Bladder wall interruption	63 (75.9)	1 (1.0)	327.6 (42.9–2501.0)	< 0.0001
Uterovesical hypervascularity	42 (50.6)	0 (0.0)	216.1 (13.0–3593.3)	0.0002
Placenta accreta/increta	n = 45	n = 143*		
Loss of clear zone	35 (77.8)	54 (37.8)	5.8 (2.6–12.6)	< 0.0001
Placental lacunae	34 (75.6)	51 (35.7)	5.6 (2.6–11.9)	< 0.0001
Bladder wall interruption	29 (64.4)	35 (24.5)	5.6 (2.7–11.5)	< 0.0001
Uterovesical hypervascularity	19 (42.2)	23 (16.1)	3.8 (1.8–8.0)	0.0004
Placenta percreta	n = 38	n = 150†		
Loss of clear zone	35 (92.1)	54 (36.0)	20.7 (6.1–70.6)	< 0.0001
Placental lacunae	31 (81.6)	54 (36.0)	7.9 (3.2–19.1)	< 0.0001
Bladder wall interruption	34 (89.5)	30 (20.0)	17.0 (7.1–40.5)	< 0.0001
Uterovesical hypervascularity	23 (60.5)	19 (12.7)	10.6 (4.7–23.7)	< 0.0001

*Includes 38 cases of placenta percreta. †Includes 45 cases of placenta accreta/increta.

Loss of the clear zone had an overall good diagnostic accuracy in detecting AIP, with a sensitivity of 84.3% (95% CI, 74.7–91.4%), specificity of 81.9% (95% CI, 73.2–88.7%), DOR of 23.8 (95% CI, 10.6–57.2), LR+ of 4.7 (95% CI, 3.1–7.1) and LR– of 0.2 (95% CI, 0.1–0.3); placental lacunae and bladder wall interruption had sensitivities of 78.3% (95% CI, 67.9–86.6%) and 75.9% (95% CI, 65.3–84.6%), respectively, while the corresponding values for specificity were 81.0% (95% CI, 72.1–88.0%) and 99.1% (95% CI, 94.8–100.0%). Finally, the presence of uterovesical hypervascularity alone had low sensitivity (50.6% (95% CI, 39.4–61.8%)) but high specificity (100% (95% CI, 96.6–100%)) in identifying AIP at the 11–14-week scan. When exploring the diagnostic performance of different ultrasound signs for detecting the different types of AIP during the first trimester, loss of the clear zone (sensitivity 92.1% (95% CI, 78.6–98.3%)), placental lacunae (sensitivity 81.6% (95% CI, 65.7–92.3%)), bladder wall interruption (sensitivity 89.5% (95% CI, 75.2–97.1%)) and uterovesical hypervascularity (sensitivity 60.5% (95% CI, 43.4–76.0%)) had a higher sensitivity for detecting placenta percreta than for detecting less severe types of AIP (Table 3).

The diagnostic performance of first-trimester ultrasound in detecting AIP according to the number of imaging signs used is also shown in Table 3. Overall, when using at least one sign, ultrasound had a sensitivity of 84.3% (95% CI, 74.7–91.4%), specificity of 61.9% (95% CI, 51.9–71.2%), DOR of 8.6 (95% CI, 4.1–19.3), LR+ of 2.2 (95% CI, 1.7–2.9) and LR– of 0.3 (95% CI, 0.1–0.4). Using two ultrasound signs to label a case as positive increased the diagnostic accuracy in terms of specificity although it did not affect sensitivity. When stratifying the analysis according to the severity of placental invasion, using at least one sign had sensitivities of 77.8% (95% CI, 62.9–88.8%) and 92.1% (95% CI, 78.6–98.3%) for placenta accreta/increta and percreta, respectively, but poor specificities (47.6% (95% CI, 39.2–56.1%) and 50.0% (95% CI, 41.7–58.3%), respectively). However, when using at least two ultrasound signs, specificity improved, to 75.5% (95% CI, 67.6–82.3%) and 76.7% (95% CI, 69.1–83.2%) for placenta accreta/increta and percreta, respectively (Table 3).

Finally, we explored which combination of ultrasound signs was associated with the optimal diagnostic accuracy in detecting AIP at the 11–14-week scan. For all types of AIP, loss of the clear zone together with placental lacunae or bladder wall interruption showed the best diagnostic performances, with respective sensitivities of 78.3% (95% CI, 67.9–86.6%) and 75.9% (95% CI, 65.3–84.6%), both having a specificity of 100% (95%

Table 3 Diagnostic accuracy of different first-trimester ultrasound signs and number of detected signs for abnormally invasive placenta (AIP) in 188 high-risk women during first trimester of pregnancy, overall and according to severity of AIP

AIP subgroup	Sensitivity (95% CI) (%)	Specificity (95% CI) (%)	DOR (95% CI)	LR+ (95% CI)	LR– (95% CI)
All AIP					
Ultrasound sign					
Loss of clear zone	84.3 (74.7–91.4)	81.9 (73.2–88.7)	23.8 (10.6–57.2)	4.7 (3.1–7.1)	0.2 (0.1–0.3)
Placental lacunae	78.3 (67.9–86.6)	81.0 (72.1–88.0)	15.1 (7.1–33.5)	4.1 (2.8–6.3)	0.3 (0.2–0.4)
Bladder wall interruption	75.9 (65.3–84.6)	99.1 (94.8–100.0)	313.0 (48.5–13259.3)	79.7 (14.5–452.2)	0.2 (0.2–0.3)
Uterovesical hypervascularity	50.6 (39.4–61.8)	100.0 (96.6–100.0)	∞ (25.8–∞)	∞ (14.3–∞)	0.5 (0.4–0.6)
Number of signs					
≥ 1	84.3 (74.7–91.4)	61.9 (51.9–71.2)	8.6 (4.1–19.3)	2.2 (1.7–2.9)	0.3 (0.1–0.4)
≥ 2	84.3 (74.7–91.4)	100.0 (96.6–100.0)	∞ (122.7–∞)	∞ (23.9–∞)	0.2 (0.1–0.3)
≥ 3	69.9 (58.8–79.5)	100.0 (96.6–100.0)	∞ (57.0–∞)	∞ (19.8–∞)	0.3 (0.2–0.4)
Placenta accreta/increta					
Ultrasound sign					
Loss of clear zone	77.8 (62.9–88.8)	62.2 (53.8–70.2)	5.7 (2.5–14.0)	2.1 (1.6–2.7)	0.4 (0.2–0.6)
Placental lacunae	75.6 (60.5–87.1)	64.3 (55.9–72.2)	5.5 (2.5–13.2)	2.1 (1.6–2.8)	0.4 (0.2–0.6)
Bladder wall interruption	64.4 (48.8–78.1)	75.5 (67.6–82.3)	5.5 (2.6–12.3)	2.6 (1.8–3.8)	0.5 (0.3–0.7)
Uterovesical hypervascularity	42.2 (27.7–57.9)	83.9 (76.9–89.5)		3.8 (1.7–4.3)	0.7 (0.5–0.9)
Number of signs					
≥ 1	77.8 (62.9–88.8)	47.6 (39.2–56.1)	3.2 (1.4–7.1)	1.5 (1.2–1.8)	0.5 (0.3–0.8)
≥ 2	77.8 (62.9–88.8)	75.5 (67.6–82.3)	10.6 (4.6–26.7)	3.2 (2.3–4.4)	0.3 (0.2–0.5)
≥ 3	62.2 (46.5–76.2)	78.3 (70.7–84.8)	5.9 (2.7–13.1)	2.9 (1.9–4.2)	0.5 (0.3–0.7)
Placenta percreta					
Ultrasound sign					
Loss of clear zone	92.1 (78.6–98.3)	64.0 (55.8–71.7)	20.4 (6.0–108.7)	2.6 (2.0–3.2)	0.1 (0.04–0.3)
Placental lacunae	81.6 (65.7–92.3)	64.0 (55.8–71.7)	7.8 (3.1–22.4)	2.3 (1.7–2.9)	0.3 (0.1–0.5)
Bladder wall interruption	89.5 (75.2–97.1)	80.0 (72.7–86.1)	33.2 (10.7–138.5)	4.5 (3.2–6.3)	0.1 (0.05–0.3)
Uterovesical hypervascularity	60.5 (43.4–76.0)	87.3 (80.9–92.2)	10.4 (4.3–25.7)	4.8 (2.9–7.8)	0.5 (0.3–0.6)
Number of signs					
≥ 1	92.1 (78.6–98.3)	50.0 (41.7–58.3)	11.6 (3.4–61.2)	1.8 (1.5–2.2)	0.2 (0.1–0.4)
≥ 2	92.1 (78.6–98.3)	76.7 (69.1–83.2)	37.5 (10.8–201.7)	4.0 (2.9–5.4)	0.1 (0.04–0.3)
≥ 3	79.0 (62.7–90.5)	80.7 (73.4–86.7)	15.3 (6.1–43.0)	4.1 (2.8–5.9)	0.3 (0.2–0.5)

DOR, diagnostic odds ratio; LR–, negative likelihood ratio; LR+, positive likelihood ratio.

CI, 96.6–100%) (Table S2). Loss of the clear zone and placental lacunae was the combination of ultrasound signs that predicted placenta accreta/increta most accurately, with a sensitivity of 75.6% (95% CI, 60.5–87.1%) and a specificity of 78.3% (95% CI, 70.7–84.8%). Finally, loss of the clear zone and either placental lacunae or bladder wall interruption showed the highest detection rates for placenta percreta, with sensitivities of 81.6% (95% CI, 65.6–92.3%) and 89.5% (95% CI, 75.2–97.1%) and specificities of 77.3% (95% CI, 69.8–83.8%) and 80.7% (95% CI, 73.4–86.7%), respectively (Table S2).

DISCUSSION

The findings of this study show that AIP can be detected from the first trimester of pregnancy in women at risk for this condition, and that ultrasound performed between 11 and 14 weeks' gestation has an overall good diagnostic accuracy for detecting all types of AIP.

The major strengths of the study are the inclusion of a population with objectively recognized and homogeneous risk factors for AIP, stratification of the analysis according to the severity of placental invasion and assessment of specificity. Retrospective design, small sample size, lack of assessment of all the ultrasound signs suggestive of AIP reported in the published literature, lack of information from early first-trimester (5–10 weeks' gestation) ultrasound and inclusion only of cases of AIP undergoing hysterectomy, represent the major limitations of the study. The results are applicable only to women with placenta previa and prior uterine scar because all cases of AIP in our population occurred in women with such risk factors. However, AIP can occur even in women with no classical risk factors for these conditions[9].

Ultrasound has been shown to have an overall good diagnostic accuracy for detecting AIP, especially when different imaging signs are integrated with maternal and pregnancy characteristics in a multiparametric diagnostic algorithm[10–12]. Despite this, it has still to be ascertained when to scan women at risk for AIP in order to detect more accurately these anomalies. Prenatal diagnosis of AIP is commonly performed during the second and third trimesters of pregnancy, but there are no robust data on first-trimester diagnosis. The present study shows that prenatal diagnosis of AIP is feasible during the first trimester of pregnancy at the time of the 11–14-week scan and that it has a good diagnostic performance, not only in detecting such disorders but also in diagnosing their severity. The main aim of first-trimester diagnosis of AIP would be to identify those women at high risk so that they can be referred to centers with expertise in the diagnosis and treatment of these disorders.

One of the major determinants of surgical outcome in women affected by AIP is the depth of placental invasion, with women affected by placenta percreta showing a greater frequency of surgical complications compared with those with placenta accreta or increta[2]. In the present study, ultrasound assessment at 11–14 weeks was able to identify about 90% of women affected by placenta percreta, showing that the optimal combination of sensitivity and specificity was achieved when predictive algorithms integrating loss of the clear zone and placental lacunae or bladder wall interruption were adopted. Furthermore, the overall diagnostic accuracy of ultrasound was higher in detecting placenta percreta than in detecting less severe types of AIP.

One of the most relevant issues when trying to diagnose AIP during the first trimester of pregnancy is which subset of women should be referred for assessment, because risk stratification for AIP in early pregnancy might not be completely clear. The major risk factors for AIP are placenta previa and previous CS[2]. However, first-trimester diagnosis of placenta previa is not completely reliable, as a significant proportion of the placenta could move away from the cervix in the second and third trimesters of pregnancy. It might be hypothesized that only women presenting with major placenta previa, defined as that completely covering the internal cervical os, should be referred for ultrasound assessment. It has been reported that the distance of the placental edge to the cervical os may help in predicting placenta previa at delivery and that, if the placenta completely covers the internal cervical os, the chance of migration is low[13].

Further large studies are needed in order to identify those women at higher risk for AIP who would benefit from early ultrasound screening for this condition and to ascertain whether combining first-, second- and third-trimester ultrasound with pregnancy characteristics and maternal risk factors could improve the diagnostic accuracy of prenatal ultrasound in detecting AIP and its variants.

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SUPPORTING INFORMATION ON THE INTERNET

The following supporting information may be found in the online version of this article:

Table S1 Logistic regression model evaluating potential independent predictors of abnormally invasive placenta (AIP) in 188 high-risk women, overall and by degree of AIP

Table S2 Diagnostic accuracy of different combinations of ultrasound signs detected in first trimester in diagnosing abnormally invasive placenta (AIP) in 188 high-risk women, overall and according to severity of AIP

Precisión en el diagnóstico de la ecografía de primer trimestre para la detección de placenta invasiva en mujeres con alto riesgo por placenta previa

RESUMEN

Objetivo Determinar la precisión en el diagnóstico de la ecografía para la detección de la placenta invasiva (AIP, por sus siglas en inglés) durante el primer trimestre del embarazo (11–14 semanas de gestación) en mujeres con riesgo de presentar esta patología.

Métodos Este estudio fue un análisis retrospectivo de datos recolectados de forma prospectiva de mujeres con riesgo de AIP, determinado por la presencia de al menos una cesárea previa (CS, por sus siglas en inglés) y/o cirugía uterina y placenta previa, a las que se les hizo una evaluación ecográfica para AIP al momento de la ecografía de la semana 11–14. Los marcadores ecográficos explorados en este estudio fueron: pérdida de la zona clara, lagunas placentarias, interrupción de la pared vesical e hipervascularidad uterovesical. El potencial de la ecografía y los diferentes marcadores ecográficos para predecir los diversos tipos de AIP se evaluaron mediante el cálculo de un resumen de las estimaciones de sensibilidad, especificidad, razón de momios del diagnóstico (RMD) y los cocientes de verosimilitud positivos (LR+) y negativos (LR−).

Resultados Se incluyeron ciento ochenta y ocho mujeres con placenta previa y al menos una cesárea previa o cirugía uterina. Todos los marcadores ecográficos empleados se asociaron significativamente con la aparición de AIP. En general, cuando se utilizó al menos un marcador ecográfico para realizar el diagnóstico, la ecografía tuvo una sensibilidad del 84,3% (IC 95%, 74,7–91,4%), una especificidad del 61,9% (IC 95%, 51,9–71,2%), RMD de 8,6 (IC 95%, 4,1–19,3), LR+ de 2,2 (IC 95%, 1,7–2,9) y LR− de 0,3 (IC 95%, 0,1–0,4), para la detección de AIP. El uso de dos marcadores ecográficos para determinar un caso como positivo aumentó la precisión del diagnóstico en cuanto a la especificidad, aunque no afectó a la sensibilidad. Entre los diferentes marcadores ecográficos, la pérdida de la zona clara tuvo una sensibilidad del 84,3% (IC 95%, 74,7–91,4%) y una especificidad del 81,9% (IC 95%, 73,2–88,7%) para la detección de AIP, mientras que las sensibilidades para las lagunas placentarias y la interrupción de la pared vesical fueron 78,3% (IC 95%, 67,9–86,6%) y 75,9% (IC 95%, 65,3–84,6%), respectivamente, y las especificidades fueron 81,0% (IC 95%, 72,1–88,0%) y 99,1% (95% CI, 94,8–100,0%), respectivamente. La combinación óptima de sensibilidad y especificidad se logró cuando en el algoritmo del diagnóstico se utilizaron al menos dos marcadores ecográficos para AIP.

Conclusiones La AIP puede ser detectada desde el primer trimestre del embarazo en mujeres con riesgo de padecer esta patología, y la ecografía realizada entre las 11 y 14 semanas tiene, en general, una buena precisión en el diagnóstico para detectar todos los tipos de AIP. Sin embargo, estos hallazgos son aplicables únicamente a mujeres con placenta previa y cicatriz uterina previa.

前置胎盘高危孕妇中孕早期超声检测异常植入性胎盘的诊断准确性

目的：确定在异常植入性胎盘（abnormally invasive placenta，AIP）高危孕妇中，超声在孕早期（孕 11~14 周）检测 AIP 的诊断准确性。

方法：根据存在至少一次剖宫产（Cesarean section，CS）和/或子宫手术且前置胎盘确定 AIP 高危孕妇，在孕 11~14 周时超声评估 AIP，对前瞻性收集的数据进行回顾性分析。本研究探讨的超声征象包括缺乏透明带、胎盘后间隙、膀胱壁回声中断、子宫膀胱血流信号丰富。通过计算敏感性、特异性和诊断比值比（diagnostic odds ratio，DOR）以及阳性（LR+）和阴性（LR−）似然比的合并估计值，评估超声和不同超声征象预测不同类型 AIP 的能力。

结果：研究纳入 188 例合并前置胎盘且有至少一次 CS 或子宫手术既往史的孕妇。所有研究的超声征象均与 AIP 的发生显著相关。总体来说，至少一个超声征象用于诊断时，超声检测 AIP 的敏感性为 84.3%（95% CI，74.7%~91.4%），特异性为 61.9%（95% CI，51.9%~71.2%），DOR 为 8.6（95% CI，4.1~19.3），LR+为 2.2（95% CI，1.7~2.9），LR−为 0.3（95% CI，0.1~0.4）。采用两个超声征象诊断阳性病例时，在特异性方面诊断准确性提高，但并不影响敏感性。在不同的超声征象中，缺乏透明带检测 AIP 的敏感性为 84.3%（95% CI，74.7%~91.4%），特异性为 81.9%（95% CI，73.2%~88.7%），而胎盘后间隙和膀胱壁回声中断的敏感性分别为 78.3%（95% CI，67.9%~86.6%）和 75.9%（95% CI，65.3%~84.6%），特异性分别为 81.0%（95% CI，72.1%~88.0%）和 99.1%（95% CI，94.8%~100.0%）。当诊断中至少采用两个 AIP 影像征象时，敏感性和特异性达到最佳结合。

结论：AIP 高危孕妇中在孕早期可以检测到 AIP，孕 11~14 周时进行超声检查对所有类型的 AIP 来说总体诊断准确性好。然而，这些结果仅能用于前胎盘置且存在瘢痕子宫的女性。

ORIGINAL PAPER