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Ultrasound features *versus* magnetic resonance imaging features for diagnosis of placenta accreta spectrum

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ABSTRACT

Objective. Prenatal diagnosis of placenta accreta spectrum (PAS) can minimize maternal morbidity and mortality. This study aims to compare the accuracy of trans-abdominal ultrasound with colour and 3D power Doppler *versus* magnetic resonance imaging (MRI) to diagnose PAS.

Materials and Methods. This study included seventy-five pregnant women with placenta previa. They underwent grey-scale trans-abdominal ultrasound with colour and 3D power Doppler and non-contrast MRI to confirm placenta previa and detect any suggestive features of placental invasion. All enrolled patients were divided into two groups based on the intraoperative assessment of placental adherence. Group 1 included cases with adherent placenta previa (n = 55), and Group 2 included non-adherent placenta previa cases (n = 20).

Results. The best ultrasonographic feature to diagnose PAS was the presence of intraplacental lacunae with turbulent blood flow by colour Doppler, with a sensitivity of 96.36%, specificity of 100%, positive predictive value of 100%, negative predictive value of 90.91%, values, and accuracy of 97.33%. The best MRI feature to diagnose PAS was the presence of dark intraplacental bands on T2-weighted images, with a sensitivity of 92.73%, specificity of 80%, positive predictive value of 92.73%, negative predictive value of 80%, and accuracy of 89.33%. However, inter-observer and intra-observer reliability were not evaluated.

Conclusions. Both ultrasound with Doppler and MRI offer high sensitivity, specificity, positive and negative predictive values, and accuracy for diagnosing PAS in high-risk women. We suggest using MRI when ultrasound is inconclusive.

INTRODUCTION

Placenta previa is an obstetric disorder with a prevalence of 52 per 10,000 pregnancy cases, in which the placental tissue partially or fully extends over the internal cervical orifice [1, 2]. It is associated with adverse maternal and foetal outcomes, including placental adhesion to the uterine wall, which

is now known as the "placenta accreta spectrum" (PAS) [3].

PAS is described as an aberrant trophoblastic invasion of a portion or all placenta into the uterine myometrium. Histopathologically, it is classified into three grades: placenta accreta (chorionic villi in touch with myometrium), placenta increta (chorionic villi infiltrating the myometrium), and placenta percreta (chorionic villi piercing the myometrium and uterine serosa and reaching the urinary bladder wall) [4].

PAS is the most common cause of "difficult" caesarean sections due to improper placental separation. Caesarean hysterectomy has been one of the options to avoid massive bleeding [5].

This condition increased maternal mortality by 7% and increased surgical morbidities such as massive blood transfusion, infection, urological injuries, fistula formation, and ICU admission [6, 7]. Prenatal diagnosis of PAS provides vital benefits, including planning to arrange all management modalities. Furthermore, high-risk instances, such as bladder involvement and cervical invasion, could be recognized, as well as massive blood loss could be avoided [8, 9].

Gray-scale ultrasound has been widely used for evaluating placental position and implantation, and it is regarded as a basis for diagnosing PAS due to its widespread availability and good diagnostic accuracy [10]. Doppler ultrasonography with 3D option could be used as a supplemental tool for the prenatal diagnosis or exclusion of PAS [11, 12].

Magnetic Resonance Imaging (MRI) relies significantly on the radiologist's skills and competence when evaluating the images [13]. When ultrasound results are questionable and unclear, or if the placenta is positioned posteriorly, MRI is advised as a supplementary imaging tool. In addition, MRI is probably used to arrange the caesarean section and/or peripartum hysterectomy when diagnosis is established by the ultrasound [14]. However, MRI can accurately identify the increta and percreta kinds of PAS, whereas the accreta type remains challenging to identify [15].

This study aims to compare the efficiency of grey-scale ultrasound with colour and 3D power Doppler *versus* MRI in diagnosing PAS and evaluate the sensitivity, specificity, positive and negative predictive values, and accuracy of each ultrasonographic and MRI feature.

MATERIALS AND METHODS

Study registration, ethical and methodological standards

This study included 75 pregnant women with placenta previa who were admitted to the Obstetrics and Gynecology Department at Kasr Al Ainy Hospital, Cairo University, with suspected placental invasion and/ or adherence by outpatient clinic 2D ultrasound. The research protocol was approved by the Research Ethics Committee. All methods were conducted following relevant guidelines and regulations.

Patient and public involvement

Our inclusion criteria were age between 18 and 40 years, BMI less than 35 kg/m^2, and singleton pregnancy at 34-37 weeks of gestation in whom placenta previa was implanted over previous caesarean scar. We excluded cases of gestational trophoblastic disease or other placental tumours, placental anomalies, uterine tumours (*e.g.*, fibroids), uncontrolled medical disorders, presence of contraindication to MRI, or cases in active labour on admission.

Data collection

After signing an informed written consent form, all cases were subjected to a history taking and general and obstetric examination. They also underwent grey-scale trans-abdominal ultrasound with colour and 3D power Doppler ultrasound and non-contrast MRI to confirm placenta previa and detect any suggestive features of placental invasion. Ultrasound and MRI for all cases were done by a senior obstetrician and radiologist, respectively, who was experienced in ultrasonographic and MRI assessment of placental invasion. Both were uninformed of each other's results to avoid bias.

Suggestive findings of placental invasion by grey scale ultrasound included loss of retroplacental sonolucent zone, loss of hyperechogenic uterine serosal bladder interface, irregular bladder wall, uterine bulging, exophytic uterine masses inside the bladder, and abnormal placental lacunae. Suggestive findings of placental invasion by Doppler ultrasound included lacunar flow pattern, sonolucent vascular areas with turbulent flow in the form of high-velocity (PSV > 15 cm/s) and low-resistance waveform, hypervascularity of the uterine-bladder interface with aberrant bridging vessels between placenta and bladder, and remarkably dilated vessels over the peripheral subplacental area.

Features suggestive of placental invasion by MRI included heterogeneous signal intensity within the placenta, dark intraplacental bands on T2-weighted images, focal thinning or absence of the myometrium at the site of placental implantation, bladder tenting as a sign of possible bladder invasion, and an outer uterine wall bulge caused by the placenta. Surgical intervention was done for all cases. After separating both rectus muscles and dissecting the parietal peritoneum, an intra-operative assessment of the placenta by the surgeon was done to reveal the condition of placenta previa regarding adherence, degree of placental adherence (accreta, increta, or percreta) and degree of myometrial invasion in case of adherent placenta (focal, partial, or total invasion). Proper dissection and mobilization of the bladder were done. If a bladder invasion or injury occurred, it was reported. All operative procedures (*e.g.*, caesarean hysterectomy, conservative management, internal iliac arteries ligation, Bakry ballon application), blood transfusion, and foetal or maternal mortalities were reported. In the case of caesarean hysterectomy, a pathological examination of the uterine specimen was done, as it is considered the gold standard to diagnose PAS and its degree of invasion.

Sample size

The sample size was -calculated to be 75 patients according to this equation: $n = [(Z\ alpha/2)/E] \times [Sn\ (1\text{-}Sn)/P]$, where Z alpha/2 = 1.96, E = The margin of error, P = proportion of PAS among abnormally implanted placentae, and Sn = Sensitivity of grey-scale ultrasound in diagnosing PAS.

Statistical analysis

The "Statistical Package for the Social Sciences" (SPSS) version 26 (IBM Corp., Armonk, NY, USA) was used to code and input the data. To summarize data, quantitative data was presented in the form of mean, standard deviation, median, minimum, and maximum, while categorical data was presented in the form of frequency and percentage. The non-parametric Mann-Whitney test was employed for quantitative variable comparisons, while Chi-square analysis was done to compare categorical data. An exact test was applied when the expected frequency was less than 5. The standard diagnostic indices of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were calculated. P-values lower than 0.05 were considered significant.

RESULTS

Seventy-five pregnant women with placenta previa were recruited according to the eligibility criteria. All enrolled patients were assigned into two groups based on the intraoperative assessment of placental adherence. Group 1 included women with adherent placenta previa or PAS (55 cases), either placenta accreta (n = 33), increta (n = 12), or percreta (n = 10). On the other hand, Group 2 included women with non-adherent placenta previa (20 cases).

The age, the body mass index (BMI), and the obstetric history are demonstrated in **Table 1**. There was no statistical significance difference between groups on age (p = 0.141), BMI (p = 0.155), gravity (p = 0.516), parity (p = 0.561), and the number of previous caesarean deliveries (p = 0. 798).

Table 2 shows the diagnostic indices for each ultrasonographic feature to predict PAS. The best ultrasonographic feature to diagnose PAS was the presence of intraplacental lacunae with turbulent blood flow by colour Doppler, with a sensitivity of 96.36%, specificity of 100%, positive predictive value of 100%, negative predictive value of 90.91%, values, and accuracy of 97.33%.

Table 3 shows the diagnostic indices for each MRI feature to predict PAS. The best MRI feature to diagnose PAS was the presence of dark intraplacental bands on T2-weighted images, with a sensitivity of 92.73%, specificity of 80%, positive predictive value of 92.73%, negative predictive value of 80%, and accuracy of 89.33%.

Operative data among the study groups are shown in **Table 4**. Conservative management had significantly succeeded in women with non-adherent placenta previa (95% of cases), compared to cases

Table 1. *Demographic data of both groups.*

	Group 1 (PAS) (n = 55)	Group 2 (Non-adherent PP) (n = 20)	P-value
Age (years)	30.25 ± 4.99 30 (23 - 39)	31.9 ± 5.32 33.5 (24 - 38)	0.141
BMI (kg/m²)	28.79 ± 2.83 29.6 (24.7 - 34.3)	29.71 ± 3.06 30.7 (25 - 33.8)	*0.155*
Gravity	3.49 ± 2.24 3 (0 - 7)	3.9 ± 2.27 4 (0 - 7)	0.516
Parity	2.91 ± 2.13 3 (0 - 7)	3.25 ± 2.2 3 (0 - 7)	0.561
Number of previous caesarean deliveries	2.22 ± 1.73 2 (0 - 7)	2.4 ± 1.98 2 (0 - 7)	0.798

Table 2. *Ultrasonographic features to diagnose PAS.*

		Group 1 (PAS) (n = 55)	Group 2 (Non-adherent) (n = 20	P-value	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value	Accuracy
Intraplacental lacunae and turbulent blood flow by colour Doppler	Positive	53 (96.40%)	0 (0%)	< 0.001	96.36%	100%	100%	90.91%	97.33%
	Negative	2 (3.60%)	20 (100%)						
Increased vascularity by colour and 3D power Doppler	Positive	32 (58.20%)	5 (25%)	0.011	58.18%	75%	86.49%	39.47%	62.67%
	Negative	23 (41.80%)	15 (75%)						
Interrupted bladder uterine interface	Positive	42 (76.40%)	3 (15%)	< 0.001	76.36%	85%	93.33%	56.67%	78.67%
	Negative	13 (23.60%)	17 (85%)						
Bulging uterine lobe inside the bladder	Positive	37 (67.30%)	0 (0%)	< 0.001	67.27%	100%	100%	52.63%	76%
	Negative	18 (32.70%)	20 (100%)						
At least one suggestive feature by ultrasound	Positive	54 (98.20%)	5 (25%)	< 0.001	98.18%	75%	91.53%	93.75%	92%
	Negative	1 (1.80%)	15 (75%)						

Table 3. *MRI features to diagnose PAS.*

		Group 1 (PAS) (n = 55)	Group 2 (Non-adherent) (n = 20	P-value	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value	Accuracy
Outer uterine bulge by the placenta	Positive	45 (81.80%)	4 (20%)	< 0.001	81.82%	80%	91.84%	61.54%	81.33%
	Negative	10 (18.20%)	16 (80%)						
Heterogeneous signal intensity within the placenta	Positive	39 (70.90%)	5 (25%)	< 0.001	70.91%	75%	88.64%	48.39%	72%
	Negative	16 (29.10%)	15 (75%)						
Dark intraplacental bands on T2-weighted images	Positive	51 (92.70%)	4 (20%)	< 0.001	92.73%	80%	92.73%	80%	89.33%
	Negative	4 (7.30%)	16 (80%)						
Bladder tenting (possible bladder invasion)	Positive	13 (23.60%)	0 (0%)	0.015	23.64%	100%	100%	32.26%	44%
	Negative	42 (76.40%)	20 (100%)						
Focal thinning or myometrial gaps	Positive	42 (76.40%)	4 (20%)	< 0.001	76.36%	80%	91.30%	55.17%	77.33%
	Negative	13 (23.60%)	16 (80%)						
At least one suggestive feature by MRI	Positive	53 (96.40%)	8 (40%)	< 0.001	96.36%	60%	86.89%	85.71%	86.67%
	Negative	2 (3.60%)	12 (60%)						

Table 4. *Operative data among the study groups.*

	Group 1 (PAS) (n = 55)				Group 2 (Non-adherent placenta previa) (n = 20)	P-value (Group 1 vs Group 2)
	Accreta (n = 33)	Increta (n = 12)	Percreta (n = 10)	All PAS cases (n = 55)		
Conservative management	3 (9.10%)	2 (16.70%)	0 (0%)	5 (9.09%)	19 (95%)	**<0.001***
Radical hysterectomy	30 (90.91%)	10 (83.33%)	10 (100%)	50 (90.91%)	1 (5%)	**<0.001***
Bilateral internal iliac artery ligation	0 (0%)	2 (16.67%)	3 (30%)	5 (9.09%)	0 (0%)	0.316
Bakry balloon tamponade	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (5%)	0.267
Bladder injury and repair	0 (0%)	1 (8.33%)	4 (40%)	5 (9.09%)	0 (0%)	0.316
Postoperative ICU admission	0 (0%)	2 (16.67%)	2 (20%)	4 (7.27%)	0 (0%)	0.568
Maternal or foetal mortality	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	NA
Number of blood units transferred	0.58 ± 0.87 0 (0 - 3)	1.08 ± 1.08 1 (0 - 3)	1.2 ± 1.39 1 (0 - 4)	0.80 ± 1.04 0 (0 - 4)	0.65 ± 1.04 0 (0 - 4)	0.521

with PAS ($p < 0.001$). On the other hand, most cases with PAS required radical hysterectomy (90.91% of placenta accreta cases, 83.33% of placenta increta cases, and 100% of placenta percreta cases), while only one case with non-adherent placenta previa ended with radical hysterectomy ($p < 0.001$). No cases with non-adherent placenta previa had bladder injury or needed postoperative ICU admission, while one case with placenta increta, and 4 cases with placenta percreta had bladder injury, and 2 cases with placenta increta and 2 cases with placenta percreta needed postoperative ICU admission. Regarding the number of blood units transferred, both groups had no significant difference ($p = 0.521$).

DISCUSSION

Main findings

PAS develops when the chorionic villi aberrantly penetrate the uterine wall. Placenta previa, recurrent caesarean deliveries, multiparity, previous abortion, and previous curettage are all risk factors for PAS. Therefore, the frequency of PAS has become higher in correlation with the rising trend of caesarean deliveries. Unfortunately, this life-threatening problem may be first discovered during delivery, necessitating urgent management with an increased risk of morbidity [16]. Therefore, early diagnosis would enable a planned strategy with the potential for therapy under better-regulated circumstances and would help lessen the blood loss linked to PAS after birth. Diagnostic challenges most likely explain the present considerable difference in the reported prevalence of PAS, which ranges between 0.5% and 0.05% of pregnancies [17].

In this study, patients underwent grey-scale trans-abdominal ultrasound with colour and 3D power Doppler ultrasound and non-contrast MRI to confirm placenta previa and detect any suggestive features of placental invasion. Fifty patients out of the adherent placenta previa group ($n = 55$) underwent caesarean hysterectomy, while the remaining five patients had conservative surgery, and only one case out of 20 cases of non-adherent placenta previa underwent caesarean hysterectomy due to severe postpartum haemorrhage. We found that the best ultrasonographic feature to diagnose PAS was the presence of intraplacental lacunae with turbulent blood flow by colour Doppler, while the best MRI feature to diagnose PAS was the presence of dark intraplacental bands on T2-weighted images. MRI may be useful as a complementary technique with ultrasound (grey-scale, colour Doppler, and 3D power Doppler) for the antenatal diagnosis of placenta accreta, but it cannot replace ultrasonography as a screening test for the diagnosis of placenta accreta. MRI can be used to confirm the diagnosis of placenta accreta further.

Interpretation and comparison with other literature

Several studies were conducted to compare the efficiency of ultrasound and MRI in early diagnosis of cases with PAS [18-21]. Despite the variety of these studies and their results, MRI is reported as a non-essential tool in the diagnosis of PAS but effective in circumstances when ultrasonography is inconclusive. Maher *et al*. (2013) reviewed 577 women who had a diagnosis of placenta previa in Saudi Arabia and examined them by both ultrasound and MRI for detection of possible placental invasion. This study showed that ultrasound had higher sensitivity and specificity than MRI (95.1% and 95.5% *vs* 85.7% and 76.9%, respectively) [22].

D'Antonio *et al*. (2013) conducted a meta-analysis that included 3,707 patients from 23 studies to define the efficiency of ultrasonography in diagnosing PAS in high-risk individuals. They found that in women with low anterior placenta and prior uterine surgery, a third-trimester ultrasound has higher sensitivity and specificity in diagnosing PAS [10]. After that, they conducted another meta-analysis that included 1010 patients from 18 [13]. They conclude that the accuracy of MRI in diagnosing PAS is nearly equivalent to ultrasonography. However, MRI could be conducted when ultrasonography is inconclusive or when the placenta is positioned laterally. In addition, MRI can clarify the topography of placental invasion needed for surgical planning.

Riteau *et al.* (2014) retrospectively reviewed the medical records of 42 pregnant women whom both ultrasonography and MRI had investigated. They found that sensitivity in diagnosing PAS with ultrasound was higher than MRI (100% *vs* 76.9%). They also found that the sign of the highest sensitivity in ultrasound diagnosis was the presence of intraplacental lacunae. However, they found that the specificity with ultrasonography was lower than MRI (37.5 *vs* 50%). They also concluded that ultrasound is the basis of screening for PAS and that MRI can be supplementary to ultrasonography, especially when there are minimal ultrasound features [23].

Satija *et al*. (2015) conducted a study on 30 pregnant women with high risk of PAS. A prenatal screening was made based on both colour Doppler ultrasound and MRI. They concluded that coloured Doppler ultrasound had higher sensitivity and specificity than MRI (87.5% and 86.4% *vs* 75% and 77.3%, respectively). Although both ultrasound and MRI still have relatively good sensitivity for prenatal screening of PAS, colour Doppler ultrasonography is still the method of choice for diagnosis, while MRI is saved for situations where ultrasound is not definitive [24].

Maged *et al*. (2017) conducted a study on 100 pregnant women with placenta previa at the Obstetrics and Gynecology Department of Kasr Al-Ainy Hospital to detect the diagnostic accuracy of Doppler ultrasound in diagnosing PAS. Abdominal Doppler ultrasound findings showed a significant difference between accreta and non-accreta groups with high sensitivity of 93.65% for intraplacental lacunae, 87.3% for loss of retroplacental clear zone, 82.54% for dilated blood vessels over peripheral subplacental area, and 47.62% for hypervascularity in the uterine bladder interface [25].

Ayati *et al*. (2017) conducted a study on 82 pregnant women suspected of PAS who underwent colour Doppler ultrasonography and MRI. They found that Doppler ultrasound had higher sensitivity than MRI (87% *vs* 76%) but lower specificity (63% *vs* 83%). The study recommended that Doppler ultrasound should be done first on high-risk women for PAS. MRI can be done when Doppler ultrasound results are inconclusive for PAS because of the high specificity of MRI [18].

El-Assaly (2020) conducted a study that included 50 pregnant women with placenta previa with clinical and ultrasonographic criteria suspecting placental invasion. The study aimed to detect the diagnostic accuracy of MRI in diagnosing PAS. It showed that MRI offered a superior choice in diagnosing PAS with a sensitivity of 72% and specificity of 100% [26]. This could be attributed to the sonographer's deficient experience. Therefore, a standardized scoring system and improved sonographer training will eliminate as many diagnostic uncertainties as feasible in ultrasound results.

Barzilay *et al*. (2020) conducted a study on 28 pregnant women at high risk for PAS in the third trimester. All women underwent ultrasonographic assessment and MRI for PAS screening, and then the diagnosis was confirmed during surgery. Compared to MRI, ultrasound was found to be more sensitive (96% *vs* 83%) and more specific (60% *vs* 40%). Thus, ultrasonography is superior to MRI in diagnosing PAS [21].

Califano *et al*. (2024) conducted a study on 81 pregnant women with placenta previa who had previous caesarean section. They found that 12 cases (14.8%) had placenta lacunae, 16 cases (19.8%) had a loss of clear space, 20 cases (24.7%) had increased vascularity between myometrium and placenta, 9 cases (11.1%) had an intracervical lake, 14 cases (17.3%) had rail sign, 14 cases (17.3%) had uterovesical hypervascularity, 5 cases (6.2%) had increased vascularity in the most lower part of lower uterine segment, 8 cases (9.9%) had disrupted bladder-myometrial interface. Cases of bladder-myometrial interface disrupted on ultrasonography had a 73-fold higher incidence of placenta accreta than those without. They concluded that the disrupted bladder-myometrial interface was the most sensitive sign for detecting placenta accreta [27].

Strength points and limitations

Our study's principal weakness point is its small sample size. In addition, inter-observer and intra-observer reliability were not evaluated. Larger population size studies are advised, with additional inclusion criteria, to achieve more useful results.

CONCLUSIONS

Both ultrasound with Doppler and MRI offer high sensitivity, specificity, positive and negative predictive values, and accuracy for diagnosing PAS in high-risk women. The decision between these modalities should depend on equipment availability and the center's competence. Our study suggests using ultrasound assessment to screen PAS cases and preserving the use of MRI when ultrasound results are inconclusive for surgical planning, as MRI is more expensive. Future research may suggest the method of choice for each PAS type.

COMPLIANCE WITH ETHICAL STANDARDS

Authors' contributions

M.A.A., A.A.G.: Conceptualization, methodology, project administration, resources, supervision, writing - review & editing. S.O.A., M.E., S.F.D.: Data curation, formal analysis, investigation, validation, writing - original draft, writing - review & editing.

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Study registration
N/A.

Disclosure of interests
The authors declare that they have no conflict of interests.

Ethical approval
The study protocol was approved by the Research Ethics Committee of Faculty of Medicine, Cairo University, with reference number (MD-180-2019). All methods were conducted following relevant guidelines and regulations.

Informed consent
All participants gave their consent after being informed of the study's goal and design. They were given the choice to leave study at any time.

Data sharing
Data are available under reasonable request to the corresponding author upon request and with the permission of Kasr El-Ainy Hospital.

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