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Reliability of Magnetic Resonance Imaging in diagnosis and assessment the depth of invasion of placental accreta in high risk gravid women

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ABSTRACT

Objectives: To evaluate sensitivity, specificity and accuracy of Magnetic Resonance Imaging (MRI) in diagnosis and assessment the depth of invasion of placenta accreta (PA) in high risk gravid women.
Materials & methods: The study included 58 pregnant women with multiple risk factors for PA. Placental mapping by ultrasound was followed by MRI when the patients were diagnosed or suspicious by ultrasound to have PA. Focal myometrial interruption, dark intra-placental band, heterogeneous placenta, focal uterine bulge and invasion to the surrounding organs were used as a sign of diagnosis of PA. The results of the MRI were compared with intraoperative findings and/or histopathological diagnosis.
Results: Placenta Previa was detected at MRI in 58 cases and PA in 49 cases. The sensitivity, specificity and accuracy of MRI in the diagnosis of PA were (100%, 75%, and 94.8% respectively) and (100%, 42.8%, and 79.3% respectively) in assessing the depth of invasion. Invasion to the surrounding organs sign was the most reliable sign in diagnosis of placenta percreta.
Conclusion: MRI is a reliable method in the diagnosis of PAbut less reliable in assessing the depth of invasion of placenta accreta and increta making the task of differentiating between them difficult. Placenta percreta diagnosed accurately by invasion to the surrounding organs.

1. Introduction

Placenta accreta (PA) is a general term for abnormal placentation, including three subtypes classified according to the depth of myometrial invasion [1]. That includes; a) placenta accreta: (the least invasive type), where the villi superficially invade the myometrium; b) placenta increta, where the villi partially invade the myometrium and, c) placenta percreta, the most invasive type, the villi invade the myometrium and the uterine serosa, with or without extension into the surrounding organs [2]. PA is associated with significant maternal mortality and morbidity, such as massive intrapartum hemorrhage (averages 3–5 L) during placental separation, disseminated intravascular coagulopathy [3], adult respiratory distress syndrome, sepsis, deep venous thrombosis, multiorgan failure, and even maternal death [1]. Previous cesarean section (CS) and placenta previa are the two major risk factors for PA [4]. The risk of PA increases from 24%in women with placenta previa and one prior cesarean delivery to 67% in women with placenta previa and three or more CS [2], advanced maternal age, multiparity, previous uterine surgery, are minor risk factors [5].

Prenatal identification of the PA is mandatory to allow proper patients counseling and optimal multidisciplinary management that can be arranged in advance trying to avoid the risks associated with a major operation and cesarean hysterectomy especially in women looking for future fertility [4]. Prenatal Ultrasound (US) is the modality of choice in the initial diagnosis of PA because of its availability, lack of ionizing radiation and it is relatively inexpensive [6], but it is unreliable in the determination of the degrees of myometrial invasion, that make adequate therapeutic planning difficult [7]. Magnetic Resonance Imaging (MRI) provides superior soft-tissue contrast, availability of multiple planes, and very good spatial resolution independent of the fetal and placental position [8]. Thus MRI might add diagnostic values and could determine the depth of myometrial invasion especially when US is inconclusive [8]. Our study aiming to evaluate sensitivity, specificity and accuracy of MRI in diagnosis and assessment of the depth of invasion of PA in high risk gravid women.

Abbreviations: MRI, Magnetic Resonance Imaging; PA, placenta accreta; US, ultrasound; CS, cesarean section; SD, standard deviation

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2. Materials and methods

2.1. Patients selection

This prospective study was approved by our institutional review board in the faculty of medicine, Assiut University, and informed consent was obtained from all patients. Between January 2016 and December 2017, 58 pregnant women were included in the study. All had placenta previa with or without multiple previous CS and other minor risk factors such as advanced maternal age and multiparity. All of them underwent initial sonographic evaluation of the placenta in the obstetric department then referred to our MRI unit in radio-diagnosis department when the patients were diagnosed or suspicious by US to have PA. We excluded women who did not have surgical and histopathological reports and the patients who contraindicated for MRI examination as those having an artificial cardiac pacemaker or metallic prosthesis not compatible with MRI or those with severe claustrophobia. The MRI final diagnosis as regards the diagnosis of PA and its subtype were correlated with the findings during CS and/or histopathological reports from hysterectomy, curetting, or fragments of myometrium adherent to the placenta, which were considered the reference gold standard. A true negative and false positive in the diagnosis of PA was defined as an easy separation of the placenta from the uterus without excessive bleeding and normal histologic findings in the placenta. We use the term "Placenta Accreta" as an umbrella term for invasive placentation.

2.2. MRI Technique

The study was conducted on Philips Achieva 1.5-T MR equipment. The patients were asked to keep the urinary bladder moderately distended during the MRI examination. All cases were examined in the supine position except the patients who could not tolerate this position examined in the left lateral decubitus position using the abdominal surface coil. The following sequences were used: T1-weighted gradient-echo with fat suppression in sagittal plane; TR/TE 600–700/20 ms using matrix 261 × 384, T2-weighted half-Fourier technique in sagittal, axial, and coronal planes perpendicular to the placenta-myometrium interface or myometrium-bladder interface; TR/TE 4000–5000/85 ms using matrix 288 × 384 and Diffusion-weighted imaging (DWI) in sagittal plane; 6000–7000 ms TR, 100 ms TE using matrix 288 × 384. The section thickness was 6–8 mm with 0.6–0.8 mm gaps, flip angle was 150 except in DWI it was 90 and field of view (FOV) was 450 × 450 mm, all these parameters used in all three sequences. The b values (sec/mm^2) used in DWI were 50, 400, 800. No intravenous injection of gadolinium was used in our study.

2.3. Image analysis

Image analysis was performed by two radiologists with 8 and 12 years experience in MRI of the female pelvis. Breath hold sagittal T2 Half Fourier images are the first to be evaluated for accurate determination of the placenta previa subtypes that are subdivided into low lying, marginal and central according to the position of the placenta to the internal cervical os. In this study, we used the following MRI signs in the evaluation of PA, focal myometrial interruption, dark intra-placental bands, placental heterogeneity, focal uterine bulge& invasion to the surrounding organs. Firstly these signs evaluated on sagittal images but must be confirmed at least on two different planes. Breath-hold Coronal T2 Half Fourier images were used for detection of focal uterine bulge or loss of normal pear shape of the gravid uterus. Sagittal breath-hold T1-weighted gradient-echo sequence was typically acquired for evaluation of normal fat plane between urinary bladder & uterus which is lost in case of placenta percreta and detection of any high signal intensity subchorionic hemorrhage, blood clots inside urinary bladder.

2.4. Statistical analysis

Data were collected and analyzed using SPSS (Statistical Package for the Social Science, version 19, IBM, and Armonk, New York). Continuous data were expressed in the form of mean ± standard deviation or median (range) while nominal data were expressed in the form of frequency (percentage). Chi-square test and Fisher Exact tests were used to compare qualitative variables. Mann-Whitney test was used to compare between two quantitative variables in case of non-parametric data. The ROC curve was used (using MedCalc software, version 15.8, Ostend, Belgium) to calculate sensitivity, specificity, positive predictive value, negative predictive value, accuracy and area under the curve (AUC) for each MRI sign in the diagnosis of each subtype of PA. The P-value considered statistically significant when $P < 0.05$.

3. Results

The 58 pregnant patients who included in our study, their ages ranged from 23 to 40 years, with means ± (SD) 31.64 ± 4.84. Their parity range from 1 to 7 with means ± (SD) 3.26 ± 1.33. All of them were in the second or third trimester with one or more risk factors for PA such as placenta previa (n = 58), 33 (56.9%) of them were centralis, marginalis in 11 cases (19%) & low lying in 14 cases (24.1%), multiple previous CS, 2 or more (n = 43, 74%), advanced maternal age ≥ 35 years (n = 20, 34.5%) and multipara with their parity 4 or more (n = 22, 38%). No statistically significant relation could be detected as regards the age, number of CS, number of parity and the type of placenta previa in correlation to the type of PA.

Among the 58 pregnant women, 49 cases (84.5%) had MRI diagnosis of PA, 19 (32.7%) cases were diagnosed as placenta accreta, 16 (27.5%) cases were increta, 13 (22.4%) cases were percreta, 1 (1.7%) case was diagnosed as ectopic pregnancy on the previous CS scar with ectopic invasion. 9 cases were diagnosed as placenta previa without abnormal placentation. By intraoperative and/or histopathologic findings, 46 cases proved to have PA, 15 cases (25.9%) were placenta accreta, 17 cases (29.3%) were increta, 13 cases (22.4%) were percreta and 1 case (1.7%) was an ectopic pregnancy. 12 cases (20.7%) were placenta previa without abnormal placentation, 3 of these cases were diagnosed as accreta by MRI.

Among the 32 cases that proved to be accrete and increta, 20 of them underwent CS without hysterectomy but with mild vaginal bleeding and slight difficulty in manual removal of the placenta, they had tissue confirmation from curetting or placental tissue containing a fragment of the myometrium. Twenty three cases underwent CS hysterectomy that included patients with increta and percreta that proved histopathologically, in addition to partial cystectomy in two cases of placenta percreta with bladder invasion. Another two cases of placenta percreta with bladder invasion underwent postnatal angioembolization followed by methotrexate aiming to save the uterus by decreasing area of the bladder and uterine infiltration by placental tissue that leads to expulsion of the placenta after 5 months without hysterectomy. The case of ectopic pregnancy on previous caesarian section scar underwent removal of the ectopic pregnancy.

MRI sensitivity, specificity and accuracy for diagnosis of PA were (100%, 75%, 94.8% respectively), and the AUC was 0.875 (Table 1). The MRI signs that were frequently seen in PA were focal myometrial interruption (84.2%), dark intra-placental bands (70.1%), heterogeneous placenta (49.1%), focal uterine bulge (45.6%) and invasion to the surrounding structure (19.2%) (Table 2).

Our data demonstrated that the focal myometrial interruption and dark intra-placental bands in patients proved to be accrete (Fig. 1), increta (Fig. 2) and percreta (Fig. 3) show very high sensitivity and very low specificity and accuracy in diagnosis of each subtype (Tables 3, 4 and 5). Heterogeneous placenta show low sensitivity, specificity, and accuracy in diagnosis of placenta accreta, increta, and percreta (Tables

Table 1
Statistical evaluation of MRI in diagnosis of PA

Sensitivity	Specificity	PPV	NPV	Accuracy	AUC
100.00	75.00	93.9	100.0	94.8	0.875

PPV: positive predictive value.
NPV: negative predictive value.
AUC: area under the curve.
PA: placenta accreta.

3, 4 and 5). Focal uterine bulge shows low sensitivity, specificity, and accuracy in diagnosis of placenta increta and percreta (Tables 4 and 5), but it shows no statistically significant difference in diagnosis in placenta accrete (its P value 0.182) (Table 2). The invasion to the surrounding organs shows no statistically significant difference in diagnosis of placenta accreta and increta (Table 2), but it shows very high sensitivity, specificity and accuracy in diagnosis of placenta percreta (Fig. 3) (Table 5).

4. Discussion

The perfect prenatal diagnosis of PA is critical as it is a potentially life-threatening obstetric condition that requires an optimal preoperative management planning and multidisciplinary approach in order to minimize the post-delivery maternal and/or neonatal morbidity and mortality [10]. Despite the fact that ultrasound is the primary imaging modality in the evaluation of placental implantation, its unreliable as it is operator-dependent and is of limited diagnostic accuracy yield in the situations like posterior placenta and patients obesity [10].

MRI is highly accurate and superior to ultrasound in the evaluation of placental attachment especially in the identification of the depth of invasion due to its excellent soft tissue resolution, multiplanar availability and high image quality independent of the fetal and placental position [8], leading to change in surgical management. Hence MRI should be routinely used in high risk pregnant women, posterior placenta and if the ultrasound findings are ambiguous [7]. Our current work prospectively evaluates the role of MRI in the diagnosis of PA. The accuracy and sensitivity of MRI in the diagnosis of PA were 94.8% and 100% respectively in our study, similar data were reported by Wang et al. [3], and Algebally et al. [11], who proved that accuracy and sensitivity of MRI were 88.7%- 96.7% and 100%–100% respectively in the diagnosis of PA. Three other studies were done by, Alamo et al. [12], Warshak, et al. [13] and Mansour et al. [14] found that the sensitivity and specificity of MRI in diagnosis of PA were 90.9%–75.0%, 88%–100% and 93.3%–85% respectively that matches the results of our study that reported the sensitivity and specificity of MRI in diagnosis of PA were (100% & 75% respectively). The high sensitivity of MRI in our study could be explained by selecting patients with more than one risk factor and most of them had suspicious or non-diagnostic findings by ultrasound. Also, we relied upon different sequences in different planes in evaluating the images. Lastly, using spin echo sequences with controlled breath hold allows better resolution with no motion artifacts from the fetus or maternal bowel peristalsis and respiration.

Over the past few years, a set of MRI signs (as focal myometrial interruption, dark intra-placental bands, placental heterogeneity, focal uterine bulge &invasion to the surrounding organs) has been established as a criteria for abnormal attachment of the placenta [9] and several publications have reported that some of these signs are associated with placental invasion [4,9,15] and [16].In our study we reported that focal myometrial interruption (84.2%) and dark intra-placental bands (70.1%) were the best MRI signs in the diagnosis of PA according to their frequency in our work, that matches the results of Alamo et al. [12], who reported that the focally interrupted myometrial border was the most frequently MRI sign seen in PA, followed by the presence of dark intra-placental bands, that could be explained by that the normal myometrium appears as a well demarcated rim of hypointense tissue, easily recognizable from the placenta on MRI.

On the contrary Algebally et al. [11] found that the most common MRI signs of placental invasion were focal uterine bulge (87%) and heterogeneity of placenta (87%) and explained that by, the focal myometrial interruption is difficult to recognize in late pregnancy due to progressive thinning of the myometrium [6]. But heterogeneous placenta (49.1%) and focal uterine bulge (45.6%) in our study were not very helpful for detecting placental invasion, that is consistent with the previously published literature by Lax et al. [9] and Alamo et al. [12], that found the heterogeneous placental and focal uterine bulge were not

Table 2
MRI signs of PA.

MRI signs	Total	Intra & post-operative findings								P-value[1]	P-value[2]	P-value[3]
		Accreta		Increta		Percreta		Normal placentation				
		No.	%	No.	%	No.	%	No.	%			
Invasion to surrounding organs.										NA	NA	0.000*
Yes	11	0	0.0	0	0.0	11	84.6	0	0.0			
No	46	15	100	17	100	2	15.4	12	100			
Focal myometrial interruption.										0.008*	0.003*	0.002*
Yes	48	14	93.3	16	94.1	13	100	5	41.7			
No	9	1	6.7	1	5.9	0	0.0	7	58.3			
Heterogeneous placenta										0.014*	0.019*	0.004*
Yes	28	9	60.0	9	52.9	9	69.2	1	8.3			
No	29	6	40.0	8	47.1	4	30.8	11	91.7			
Focal uterine bulge										0.182	0.001*	0.011*
Yes	26	5	33.3	12	70.6	8	61.5	1	8.3			
No	31	10	66.7	5	29.4	5	38.5	11	91.7			
Dark intra-placental band										0.038*	0.029*	0.004*
Yes	40	11	73.3	13	76.5	12	92.3	4	33.3			
No	17	4	26.7	4	23.5	1	7.7	8	66.7			

P-value[1] calculated the p-value of each MRI sign in placenta accreta subtype compared to the normal placentation.
P-value[2] calculated the p-value of each MRI sign in placenta increta subtype compared to the normal placentation.
P-value[3] calculated the p-value of each MRI sign in placenta percreta subtype compared to the normal placentation.
PA: placenta accreta.
NA: not applicable.
* Means the result will be statistically significant when $P < 0.05$.

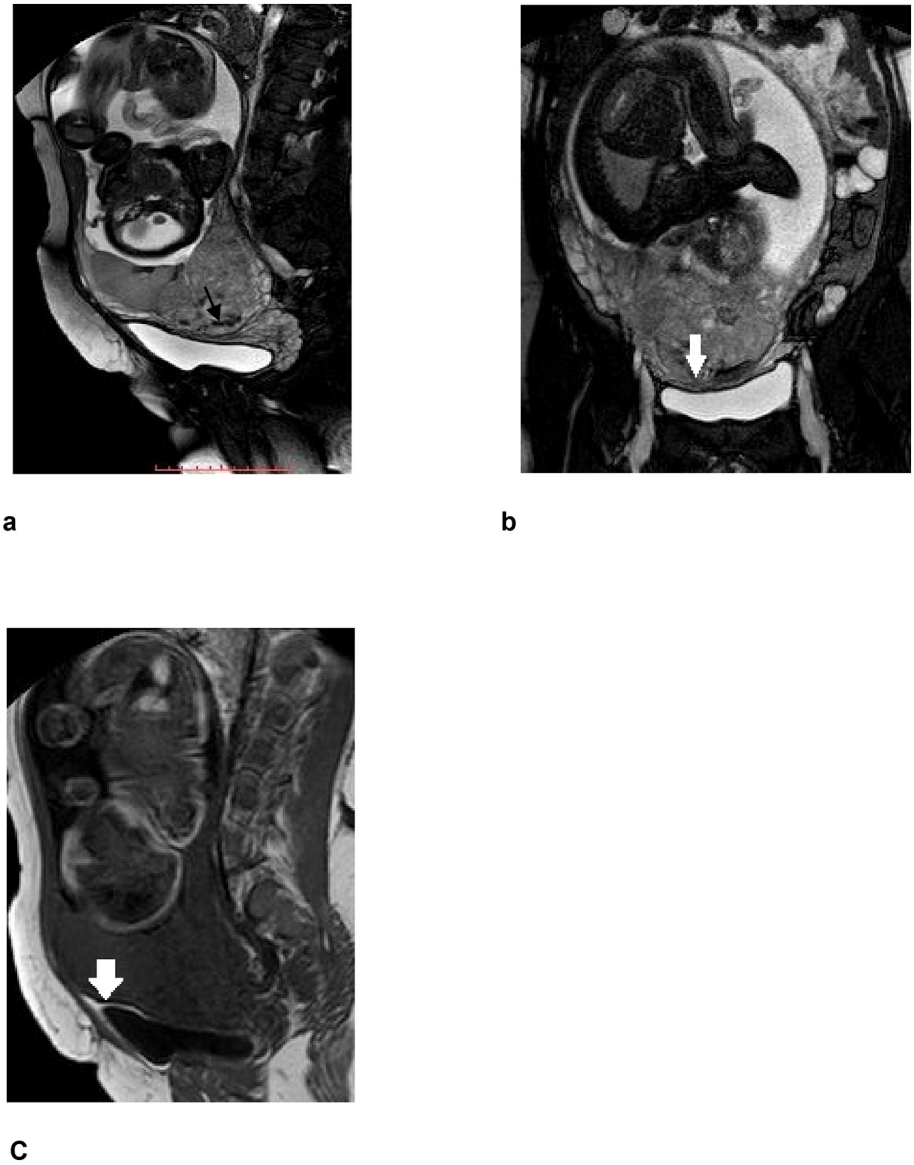

Fig. 1. Placenta accreta in a 29-year-old woman (a) placenta previa centralis and dark intra-placental band (black arrow) seen on sagittal T2-HASTE MRI. (b) Coronal T2-HASTE MRI clearly demonstrates heterogeneous placenta with focal myometrial interruption (white arrow). (c) The preserved fat plane between the bladder & uterine wall (white arrow) is clearly demonstrated in Sagittal T1 WI.

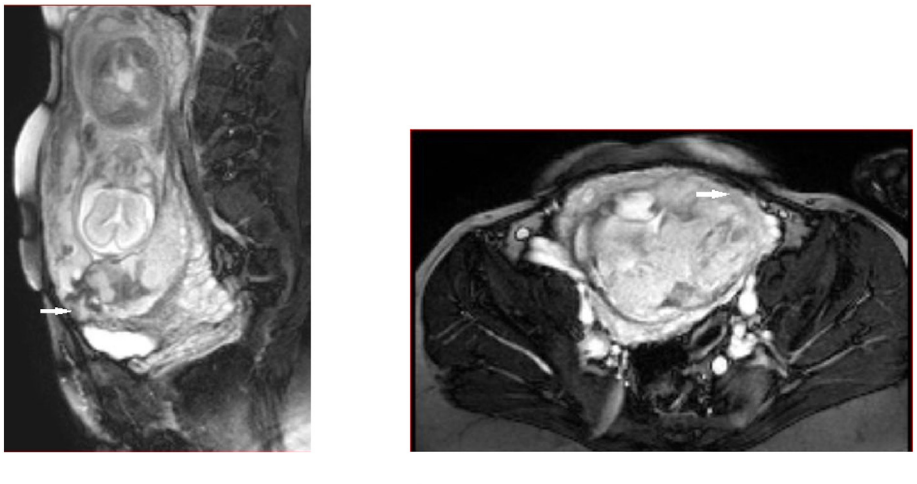

Fig. 2. Placenta increta in 33 years old woman (a) sagittal T2 HASTE MRI shows Placenta previa centralis with heterogeneous signal intensity, dark intra-placental bands and focal placental invasion of the myometrium at the site of previous CS scar (white arrow). (b) Focal myometrium interruption and placental invasion at the left anterolateral uterine wall is better seen in axial T2 HASTE MRI (white arrow).

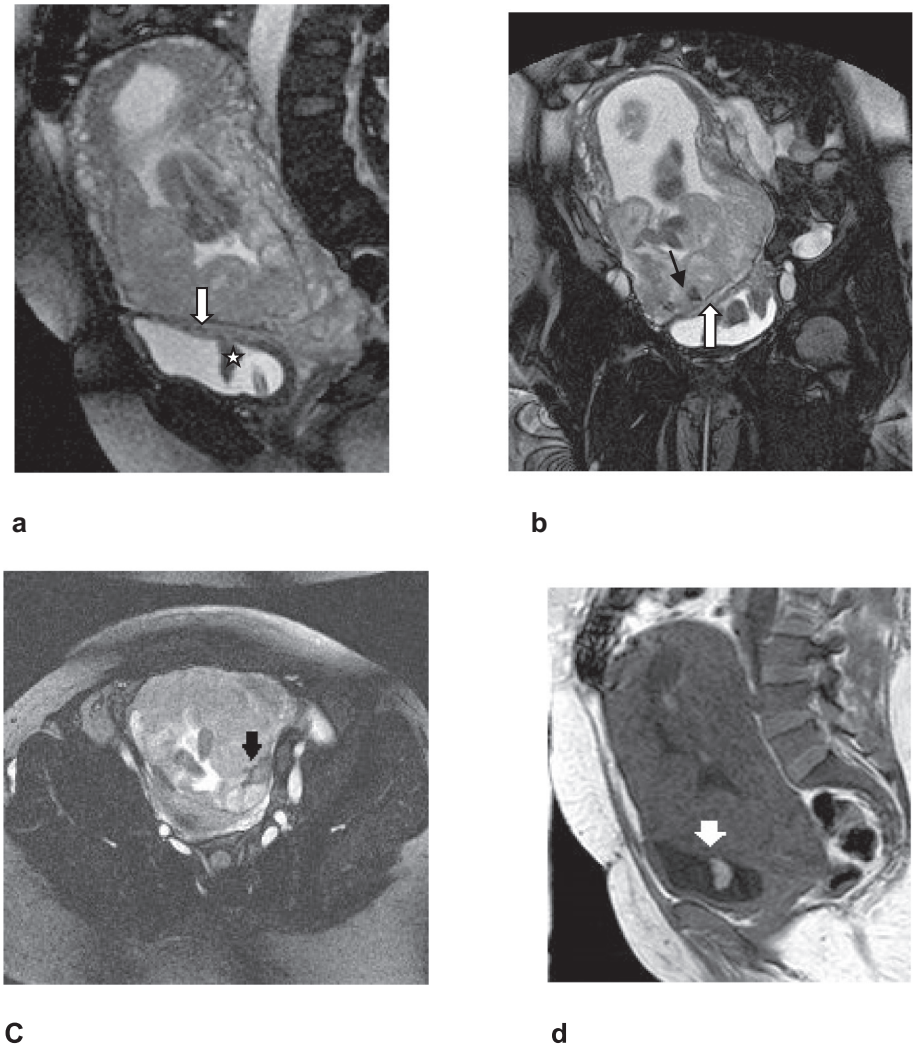

Fig. 3. Placenta percreta in a 32-year-old woman (a) sagittal T2-HASTE MRI shows placenta previa centralis with bladder invasion by the placenta at its dome (white arrow) appear as high signal intensity & blood clots inside (white star). (b) Coronal T2-HASTE MRI demonstrates heterogeneous placenta, dark intra-placental bands (black arrow), focal myometrial bulge & interruption (white arrow). (c) Dark intraplacental band (black arrow) also seen in axial T2-HASTE MRI. (d) Obliteration of fat plane between bladder & uterus (white arrow) is better seen in saggital T1WI.

Table 3
MRI signs of placenta accreta.

MRI signs of placenta accreta	Sensitivity	Specificity	PPV	NPV	Accuracy	AUC
Focal myometrial interruption	93.3	18.6	28.6	88.9	37.9	0.560
Dark intra placental band	73.3	30.23	26.8	76.5	41.4	0.518
Heterogeneous placental	50	53.49	31	79.3	55.2	0.567

PPV: positive predictive value.
NPV: negative predictive value.
AUC: area under the curve.

Table 4
MRI signs of placenta increta.

MRI signs of placenta increta.	Sensitivity	Specificity	PPV	NPV	Accuracy	AUC
Focal myometrial interruption	94.12	19.51	32.7	88.9	41.4	0.568
Dark intra-placental band	76.47	31.7	31.7	76.5	44.8	0.541
Heterogeneous placenta	52.94	51.22	31	72.4	51.7	0.521
Focal uterine bulge	70.59	63.41	44.4	83.9	65.5	0.670

PPV: positive predictive value.
NPV: negative predictive value.
AUC: area under the curve.

Table 5
MRI signs of placenta percreta.

MRI signs of placenta percreta	Sensitivity	Specificity	PPV	NPV	Accuracy	AUC
Focal myometrial interruption	100	20	26.5	100	37.9	0.600
Dark intra placental band	92.31	35.56	29.3	94.1	48.3	0.639
Heterogeneous placenta	69.23	55.78	31	86.2	58.6	0.624
Focal uterine bulge	61.54	57.78	29.6	83.9	58.6	0.597
Invasion to the surrounding organs	84.62	100	100	95.7	96.6	0.923

PPV: positive predictive value.
NPV: negative predictive value.
AUC: area under the curve.

helpful in the detection of abnormal placentation, as they found that the focal uterine bulge also occurs in true negative subjects. Furthermore, heterogeneous placenta occurs in normal pregnancy and also in late pregnancies due to the presence of hemorrhagic foci as a result of high vascularity and irregular high flow distribution of the placenta. Also, Blaicher et al. [17], and Bour et al. [18], reported that placental heterogeneity varies according to the gestational age and was not significantly associated with the diagnosis of invasive placenta.

As the detection of placental invasion is important, determination of the depth of invasion is critical as the deeper the invasion, the greater risk and the higher rate of complications. Focal myometrial interruption and dark intra-placental bands were the most sensitive MRI signs in diagnosis of placenta accreta, increta and percreta (93.3%–73.3%, 94.12%–76.47%, and 100%–92.31% respectively) in our study (Tables 2, 3, 4), but none of them was specific to any subtype of the PA, thus these signs are sensitive in detection of abnormal placental attachment but unreliable in differentiation between each subtype or in determination of the depth of invasion. In agreement with our result Derman et al. [2] reported that the dark intraplacental bands are not specific for identification of placental invasion and explained that by visualization of this sign in placental infarction, intervillous thrombus and also in normal placentas. Heterogeneous placenta and the focal uterine bulge in our study showed low sensitivity and specificity in the diagnosis of all types of PA (Tables 4, 5). These data match the data reported by Lax et al. [9], and Teo et al. [15], that proved the thick intra-placental T2 dark bands, marked placental heterogeneity, and bulging of the lower uterine segment are MRI signs of invasive placentation but they were unreliable signs to define the degree of placental invasion.

Identification of placenta percreta was very important because it often requires highly aggressive and specialized surgical procedures for therapy. Direct invasion of the pelvic structure was found to be the most reliable sign in the diagnosis of placenta percreta in our study with high sensitivity, specificity, and accuracy (84.62%, 100%, and 96.6% respectively). Thus the accuracy of MRI in assessing the depth of invasion in our study was 79.3%, this could be explained by a large number of false positive cases (n = 12), this result differs from the result of the study done by Algebally et al. [11], that demonstrated 100% accuracy of MRI in assessing the depth of invasion that could be explained by using MRI with Gadolinium in this study. A large number of false positive in our study leads to very low specificity (42.8%) of MRI in assessing the depth of invasion that matched the result of the study done by Alamo et al. [12], which its MRI specificity was 43.1% but its sensitivity was 62.2% for junior readers that differ from our sensitivity which was 100%, that could be explained by zero number of false negative cases in our study.

Indeed, a significant barrier to optimizing the differentiation between placenta accreta and increta is the lack of reliable and specific MRI signs for each type, however, the task to differentiate between placenta percreta from accreta and increta has proven to be the easiest one in case of invasion of the surrounding organs.

The strength of our study is that: 1) US was used for primary scanning of cases of placenta previa and PA, 2) MR signs of PA were estimated without the use of gadolinium, which is the approach most suitable for gravid patients. However, there are some limitations to our study, first; this study was carried out in a single center, so these results are specific for this center, multicenter research is recommended. Second; we had a small number of each subtype of the PA (placenta accrete = 15 cases, placenta increta = 17, placenta percreta = 13), consequently, the Logistic regression test cannot be made. Finally, this study was performed in high-risk women with ultrasound findings suspicious for placenta accrete referred for MR imaging and, thus, is not representative of the general obstetric population.

5. Conclusions

In conclusion, Different MR signs are helpful in the diagnosis of PA but these signs are unreliable in the differentiation of placenta accreta from Increta, except invasion to the surrounding organs is highly sensitive, specific and accurate in diagnosis placenta percreta. So inclusion of the MRI of the placenta is a crucial step in the routine evaluation of patients at risk and when US findings were equivocal for abnormal placentation as it may change the surgical plans especially in case of placenta percreta with a favorable outcome.

Declaration of Competing Interest

The authors whose names are listed immediately below certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria, educational grants, participation in speakers, membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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