Diagnostic Value of MRI in Placental Adhesive Disorders in Pregnancy

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Abstract

Background The spectrum of placental adhesive disorders (PAD) forms an important cause for emergency cesarean hysterectomy, requiring an accurate prenatal diagnosis for optimal obstetric management.

Purpose The aim of this study was to assess the utility of magnetic resonance imaging (MRI) and to identify the individual MRI features that are most useful in the evaluation of PAD.

Materials and Methods This was a retrospective review of the MRI of 24 women with abnormal placentation, confirmed using histopathology/intraoperative findings as the reference standard. Patients were categorized as negative or positive for PAD (placenta accreta, increta, and percreta) on MRI and compared with the reference standard. We assessed the diagnostic performance of MRI and the features that best correlated with the presence of PAD.

Results Among the 24 women (mean age: 29.8 years) with risk factors, 16 had PAD (6 accreta, 7 increta, and 3 percreta). There was a history of previous lower segment cesarean section and placenta previa in 14 (87.5%). MRI could identify the presence of PAD in all (100% sensitivity) and its absence in three out of eight patients (37.5% specificity). The features with highest sensitivity were intraplacental dark bands (100%), myometrial thinning/loss of interface with myometrium (100%), placental heterogeneity (75%), and uterine contour abnormality (75%).

Conclusion MRI is an important modality for the investigation of PAD in suspected cases, with excellent sensitivity and good accuracy. Identifying the presence of risk factors, low-signal-intensity bands, and thinning/loss of placental–myometrial interface will aid in its diagnosis.

Keywords
- MRI
- placenta accreta
- placenta previa
- abnormal placentation
- pregnancy

Introduction

Placental adhesive disorders (PAD), otherwise known as morbidly adherent placenta or placenta accreta spectrum (PAS) disorders, occurs when the chorionic villi invade the myometrium due to a defect in the decidua basalis. It constitutes a spectrum of placenta accreta, increta, and percreta with increasing depth of invasion and severity.[1] In placenta accreta (accreta vera), the villi are attached to the

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myometrium without muscle invasion. There is myometrial invasion in placenta increta and of the serosa and beyond in placenta percreta.[2] It is an important cause for postpartum hemorrhage, intraoperative complications like bladder and ureteral injury, prolonged requirement for intensive care with its associated complications of ventilatory support, and pulmonary embolism.

Placenta previa and prior cesarean section are the major risk factors, with incidence rates of 3% for the first delivery and 40 to 67% for the third to fifth deliveries, when the former and 24% when both factors are present.[3,4] The less commonly encountered risk factors include advanced maternal age, prior uterine surgeries, recurrent abortions, and grand multiparity.[5–7] With the increasing rates of cesarean delivery, the incidence of PAD has been estimated to show an approximately 13 times increase.[8–10]

PAD is the most common cause for emergency cesarean hysterectomy, contributing up to one-third to one-half of all cases.[11] Given its significantly associated morbidity, accurate prenatal diagnosis helps in organizing in advance and thereby planning optimal obstetric management.[12] Ultrasonography that is performed at around 32 weeks of gestation is the primary tool in evaluating abnormal placentation[1,13]; however, its usefulness in posteriorly placed placenta and reliability in differentiating the severity of invasion is questionable. Magnetic resonance imaging (MRI) plays a crucial role in providing detailed and useful information in instances where it is suspicious or inconclusive on ultrasound.

The goal of this study was to establish the role of MRI in identifying abnormal placentation and to identify the predisposing factors and imaging features that best predict the presence of PAD.

Materials and Methods

This was an institutional review board-approved (IRB no: 11674) retrospective review of abdominal or pelvic MRIs of all women suspected to have abnormal placentation over a period of 15 years (2003–2018) undertaken by the departments of radiology, obstetrics, and gynecology in a tertiary care center. The cases were obtained by appropriate keyword search of the Picture Archiving and Communication System (PACS) database, of the MRI pelvis and MRI abdomen-pelvis studies done during this period for suspected abnormal placentation. All cases had a final diagnosis that was made using histopathology or intraoperative findings when hysterectomy was not performed.

The MRI was performed with an external surface coil on a 1.5T scanner (Siemens, Avanto, Germany). The examination protocol included T2-weighted (T2W) fast spin echo images in axial and coronal planes, T1-weighted (T1W) and spectral attenuated inversion recovery images in axial plane, and T2W high-resolution images through the uterus in three planes (axial, coronal, and sagittal). Matrix size (368×291 and 334×377), field of view (220–230 mm), slice thickness (3 mm) and slice gap (0.3mm) was used for the high-resolution images. Breath-holding technique was not used to avoid patient discomfort. Gadolinium injection was not done in view of concerns regarding its usage during pregnancy.

Image Analysis

Two radiologists with 4 and 10 years of experience who were blinded to the final diagnosis reviewed the MRI studies on PACS workstation (provided by GE Healthcare, Barrington, Illinois, United States). The following imaging features as described by Lax et al[2,14] for identifying PAD was documented: placental position (anterior/posterior), placenta previa (low lying, marginal, complete and central),[15] dark intraplacental bands, placental heterogeneity, uterine contour abnormality, loss of interface with myometrium with myometrial thinning, shaggy external contour, and frank extrauterine placental invasion (EUPI).

The MRI features used for the identification of PAD were defined as follows:

- Intraplacental T2 dark bands: Dark linear bands measuring more than 6mm in thickness traversing through and often contacting the maternal surface of the placenta on T2W high resolution images.[16]
- Placental heterogeneity: Variation in the internal signal of the placenta on both T2W and T1W sequences due to a combination of abnormal T2 dark bands, hemorrhage, and abnormal vasculature within the placenta.
- Uterine contour abnormality: Deviation of the external surface from the expected plane caused by abnormal bulge or retraction of placental tissue, resulting in lumpy contour and rounded edges.[17]
- Loss of placental-myometrial interface (myometrial invasion): Loss of a thin dark line over lying the placental bed and thinning of myometrium to less than 2 mm.[18]
- Shaggy external contour: Markedly irregular external contour of the uterus giving a shaggy appearance to the surface.[1,16]
- EUPI: Direct invasion of adjacent pelvic structures, tenting of the urinary bladder or focal exophytic mass.[17]

The two observers documented the various imaging findings in consensus. ►**Fig. 1** depicts these MRI signs on T2W high-resolution images.

The electronic medical records and histopathology reports were accessed from the clinical workstation after the imaging interpretation to avoid interpretation bias. The patients' age, indication for performing MRI, gestational age, parity, details of prior cesarean sections, other medical risk factors, and patient's outcome were recorded.

Statistical Analysis

All the statistical analyses were performed using SPSS 16.0 (IBM SPSS Analytics 16.0 software Chicago, Illinois, United States). Summary statistics were used for reporting demographic and clinical characteristics. Student's *t*-test was used for analysis of continuous data. Chi-squared test was performed for categorical variables. The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were evaluated for each MRI feature. Fisher's exact test was used to determine the statistical significance and the

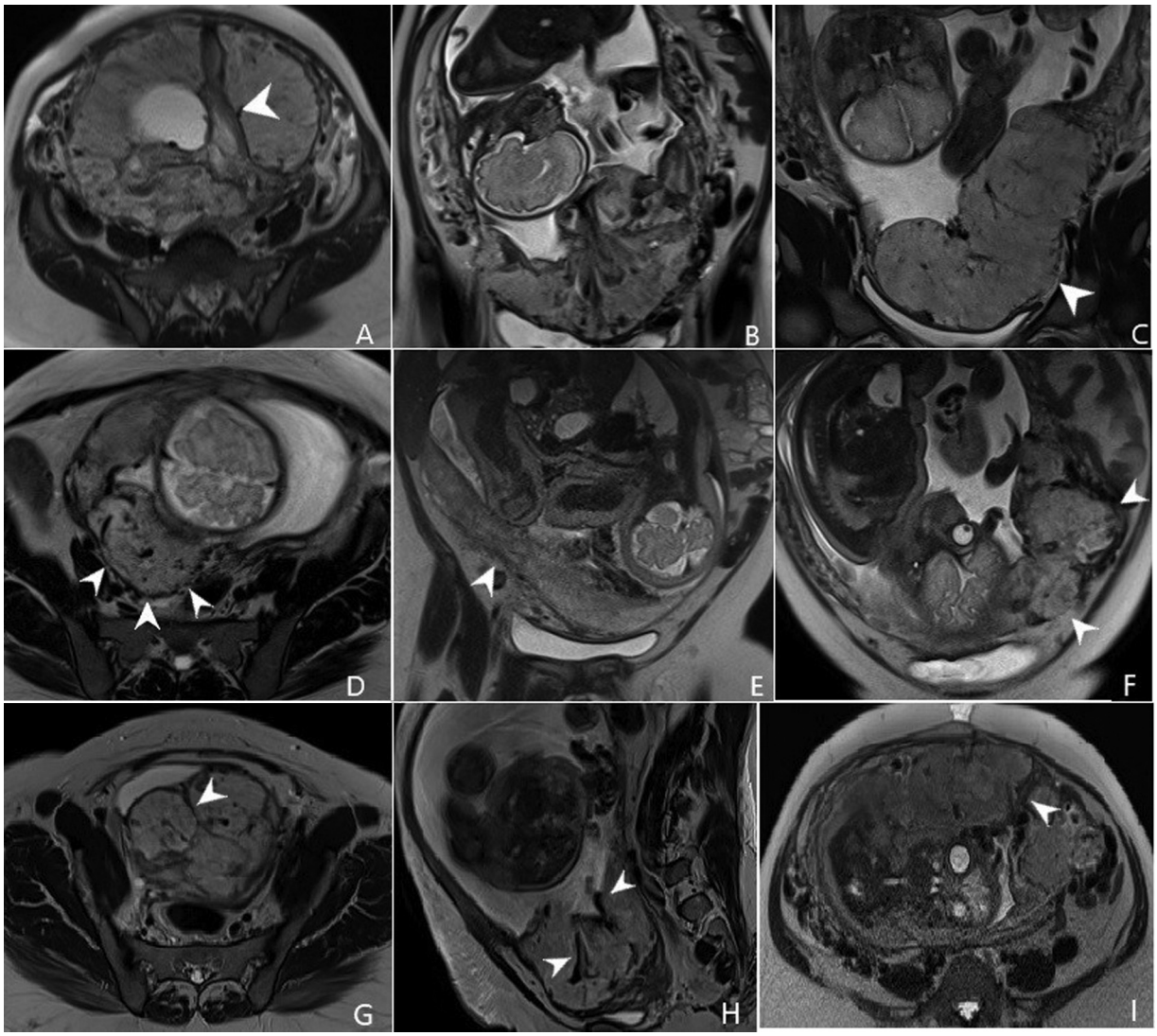

Fig. 1 Magnetic resonance imaging signs used to predict placental adhesive disorders. All images are from T2-weighted high-resolution axial, coronal, and sagittal sequences. (**A**) Intraplacental dark bands (*arrowhead*) seen as a linear thick low intensity structure contacting the maternal and fetal surfaces. (**B**) Heterogeneous placenta, due to overall heterogeneity in addition to the abnormal vasculature and dark bands. (**C**) Loss of hypointense interface between the placenta and myometrium and myometrial thinning to less than 2 mm (*arrowhead*). (**D** and **E**) Contour abnormality due to deviation of the uterine serosa from the expected plane (*arrowheads* depicting contour bulge and retraction respectively). (**F**) Extrauterine placental invasion (*arrowheads*), seen as focal protrusions of the placenta into the parametrium. (**G–I**) Various appearances and thickness of intraplacental dark bands (*arrowheads*), associated with placental adhesive disorder.

differences were considered significant at *p*-value less than 0.05. Confidence intervals (CIs) for sensitivity, specificity, and accuracy are "exact" Clopper-Pearson CI. CIs for the predictive values are the standard logit CI given by Mercaldo et al.[19]

Results

Patients

The number of patients who underwent MRI with a suspicion of PAD was 26. Among these, two were excluded due to an alternative diagnosis of hematoma and uterine fibroid on imaging. Twenty-four women with mean age of 29.5 years and range of 20 to 39 years were included for final analysis.

The suspicion of abnormal placentation and hence indication for MRI in these patients were mainly due to previous cesarean sections or placenta previa or both (19 patients), retained placenta ($n = 1$), unexplained postpartum hemorrhage or discharge per vagina ($n = 3$), and abdominal pain ($n = 1$). The mean gestational age when the MRI was performed was 32.2 ± 5 weeks with a range of 18 to 38 weeks. The number of gestations among these women ranged from one to six gestations; majority were in their second ($n = 11$) or third ($n = 7$) gestations; while two women were grand multipara. Five (20.8%) women had a history of prior uterine surgery, which included myomectomies, laparoscopic evaluation for infertility, and dilatation and curettage. ►**Fig. 2** depicts the different types of placenta previa that can be seen in these patients.

Sixteen (66.6%) patients were diagnosed with PAD as per the reference standards used. Among these, PAD was classified as follows: Placenta accreta ($n = 6$), increta ($n = 7$), and

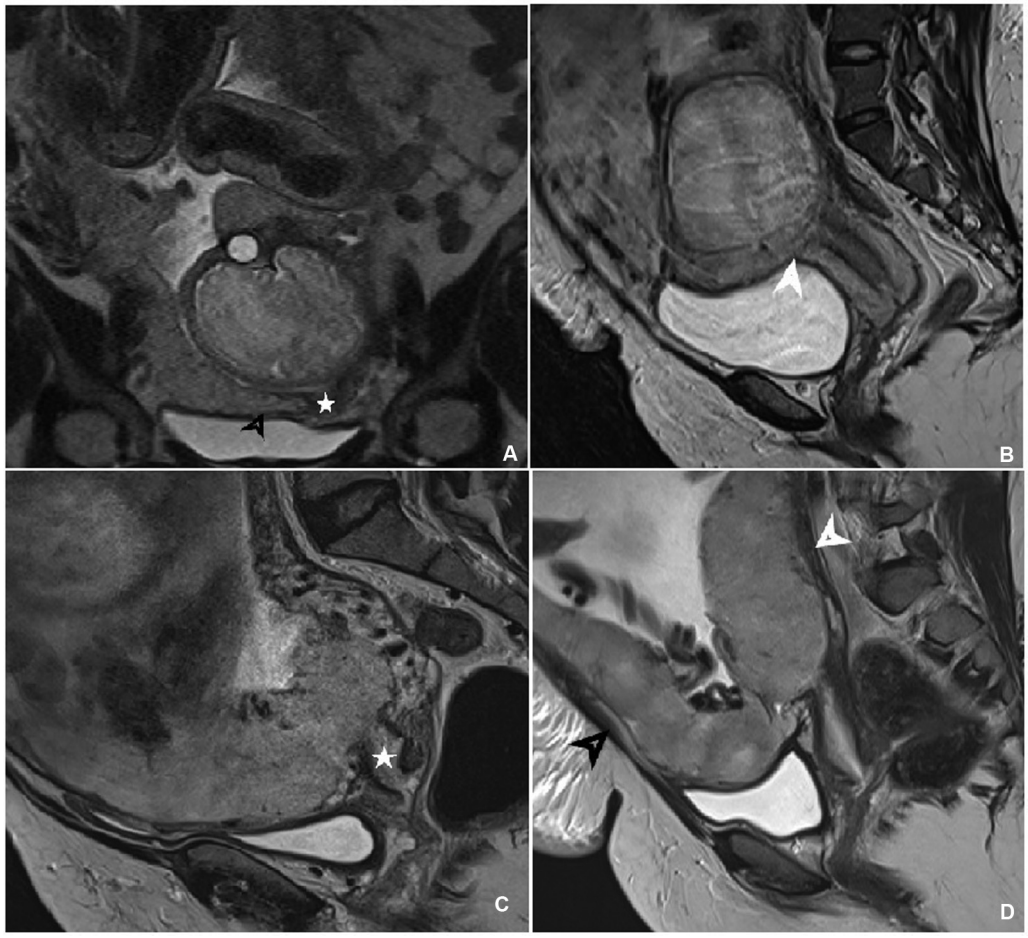

Fig. 2 Different types of placenta previa based on the relationship to the internal cervical os. T2-weighted high-resolution coronal and sagittal images depicting: (**A**) low lying placenta (*arrowhead*) in the lower uterine segment, but not encroaching the internal os (*star*). (**B**) Marginal placenta previa, where the placental tissue (*arrowhead*) reaches the margin of the internal cervical os. (**C**) Complete placenta previa completely covering the internal os (*star*). (**D**) Central placenta previa, where equal portions of the placenta are present on the anterior and posterior (*black and white arrowheads*) lower uterine segments.

percreta ($n = 3$). ►**Fig. 3** shows representative cases of PAD, classified based on the depth of invasion.

Among these, 11 (68.7%) patients underwent cesarean hysterectomy, in which two were treated with uterine artery embolization with subsequent expulsion of placenta, one patient underwent laparotomy with uterine repair, and in two cases, the placenta could be removed completely during the cesarean section. Bladder injury was encountered in five (31.2%) cases during surgery, and excessive bleeding in four (25%) with need for uterine artery ligation in two cases. A history of prior cesarean section was present in 14 (87.5%) patients and six among these with more than one cesarean sections.

MRI Features of Placental Adhesive Disorders

►**Table 1** summarizes the clinical and imaging features of patients included in the study.

MRI could successfully diagnose all patients in our series ($n = 16$) with PAD. However, MRI over-diagnosed PAD with five false positive cases. The sensitivity, specificity, NPV, PPV, and accuracy of MRI for its ability to diagnose PAD were 100% (CI: 79.4–100%), 37.5% (CI: 8.5–75.5%), 100%, 76.2% (65.1–84.5%), and 79.17% (CI: 57.8–92.8%). However, varying sensitivity for assessing the severity of PAD was noticed (33.3% for accreta, 42.8% for increta and 66.6% for percreta). The diagnostic odds ratio (DOR) was 21 (95% CI: 0.93–473.8).

►**Table 2** summarizes the diagnostic performance of various MRI signs in predicting PAD. Intraplacental dark bands (IPDBs), placental heterogeneity, uterine contour abnormality, and loss of interface with myometrium with myometrial thinning were the MRI signs that were significantly associated with PAD ($p < 0.05$).

IPDBs was a feature seen in all patients (sensitivity: 100%, specificity: 50%, PPV: 80%, NPV: 100%, accuracy: 83.3%, *p*-value: 0.007); heterogeneous intraplacental signal in 12 patients (sensitivity: 75%, specificity: 75%, PPV: 85.7%, NPV: 60%, accuracy: 75%, *p*-value 0.032); uterine contour abnormality in 12 patients (sensitivity: 75%, specificity: 87.5%, PPV: 92.3%, NPV: 63.6%, accuracy: 79.2%, *p*-value: 0.008); loss of interface with thinning of myometrium in all patients (sensitivity: 100%, specificity: 37.5%, PPV: 76.2%, NPV: 100%, accuracy: 79.2%, *p*-value 0.028).

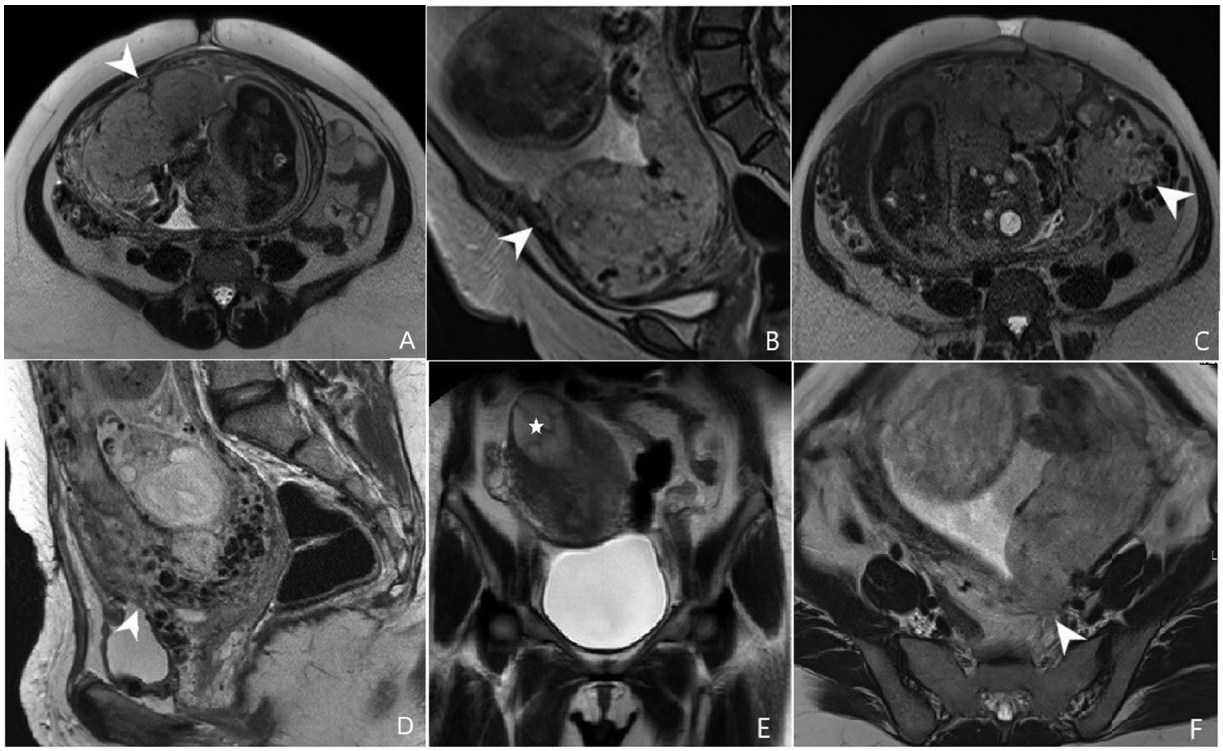

Fig. 3 Classification of placental adhesive disorders based on depth of invasion. All images are from T2-weighted high-resolution axial, sagittal, and coronal sequences with histopathologically proven depth of invasion. (**A**) Placenta accreta (*arrowhead*) seen as focal adherence of the placenta with a placental dark band. (**B**) Invasion of myometrium in placenta increta (*arrowhead*). (**C**)- Invasion beyond the serosa into the parametrium in placenta percreta (*arrowhead*). (**D**) Placenta percreta invading the bladder dome (*arrowhead*), note the normal thickness and clear definition of the anterior and posterior bladder walls. (**E**) Magnetic resonance imaging in a case of retained placenta, depicting myometrial invasion (*star*), representing placenta increta. (F) Another example of placenta increta seen as marked myometrial thinning with loss of hypointense uteroplacental interface (*arrowhead*).

Discussion

The incidence of PAD during pregnancy has been increasing mainly owing to the increased rates of cesarean sections.[20] History of prior cesarean sections and placenta previa is the most significant and frequent risk factor described in many series.[1,21] The risk also rises with increase in the number of cesarean sections, that is, more than or equal to 3 cesarian sections.[22] Advanced maternal age, high parity, multiple abortions with curettage, and anterior low location of the placenta are the other known risk factors.[5] As PAD can be life threatening, cesarean hysterectomy is required in many cases that in turn has its own complications like ureteral and bladder injury when performed in an emergency setting. Other life-threatening complications can also arise due to prolonged intensive care unit stay, notably deep vein thrombosis and pulmonary embolism. Severe PAD can result in massive hemorrhage during placental separation, retention of placenta and might even require pre-emptive uterine artery embolization. Hence, prior knowledge and accurate diagnosis of this condition allow treatment planning, thereby minimizing maternal morbidity and mortality. Ultrasonography and MRI have been used in the preoperative diagnosis, with several studies showing MRI to be a sensitive tool when performed between 24 and 30 weeks of gestation. Comparative studies have shown ultrasonography and MRI to be comparable in diagnosing PAD,[23,24] with MRI being better at identifying the severity of infiltration.[25] As per the Society of Abdominal Radiology and European Society of Urogenital Radiology (SAR/ESUR) joint consensus statement, MRI is a valuable adjunct to ultrasound, allowing assessment of the topography and depth of invasion in PAD.[26] As MRI is noninvasive, radiation free and with added benefit of reduced operator dependence, it is an important diagnostic modality for planning treatment in these patients. With this knowledge in the background, we did a retrospective review of cases to establish the diagnostic value of MRI and to identify the most useful signs that would help in making an accurate diagnosis of PAD.

Several studies have demonstrated the diagnostic accuracy of MRI in PAS. The sensitivity of MRI in some of the other studies ranges between 72 and 100%.[2,11,12,21–25,27–30] In a systematic review and meta-analysis of 18 studies including 861 patients, MRI showed a sensitivity of 89%, specificity of 87%, and DOR of 37.4 in the diagnosis of PAD.[31] Our study confirms that MRI is highly sensitive in identifying the presence of PAD with 100% sensitivity, however, with a lower and varying sensitivity in diagnosing the severity of PAD (33.3% for accreta, 42.8% for increta, and 66.6% for percreta). It was also noted that MRI tends to assign a higher grade to the degree of PAD. Certain other studies have also noted this difficulty in differentiating placenta accreta from increta and percreta.[1] The specificity in identifying the presence of PAD is not as good as described in other studies, which is 37.5% as

Table 1 Clinical and MRI findings in 16 patients with PAD and 8 patients without PAD as per reference standard

	PAD ($n = 16$)	No PAD ($n = 8$)
Age	24–36 years	24–35 years
Cesarean sections	14 (87.5%)	7 (87.5%)
Other uterine procedures	4	1
Placenta previa	14 (87.5%)	5 (62.5%)
- Low	3	0
- Marginal	2	3
- Complete	2	0
- Central	7	2
Placental position		
- Anterior	5	4
- Posterior	1	2
- Anterior and posterior	8	2
- Fundal	2	0
PAD		
- Accreta	6	
- Increta	7	
- Percreta	3	
MRI signs:		
Intraplacental dark bands	16 (100%)	4 (50%)
Heterogeneous placenta	12 (75%)	2 (25%)
Thinned myometrial zone	16 (100%)	5 (62.5%)
Uterine contour abnormality	12 (75%)	1 (12.5%)
Shaggy external contour	4 (25%)	0 (0%)
Extrauterine placental invasion	5 (31.25%)	1 (12.5%)
Treatment:		
Cesarean section with removal of placenta	2	6
Cesarean hysterectomy	11	1
UAE	2	0
Laparotomy	1	1
Complications:		
Blood loss	4	1
Ureteric/ bladder injury	5	0
Pulmonary embolism/ DVT	0	0
Mortality	0	0

Abbreviations: DVT, deep vein thrombosis; MRI, magnetic resonance imaging; PAD, placental adhesive disorder; UAE, uterine artery embolization.

opposed to 65 to 100%.[28] The comparatively low specificity could be because most of our patients were evaluated in the third trimester, during which time assessment is more technically difficult due to physiological thinning and distension of the uterine wall. In addition, the use of gadolinium and diffusion-weighted imaging (DWI) in other studies could have favorably affected specificity.

The MRI criteria for diagnosing PAD are based on direct placental invasion into the uterus like indistinct interface with the myometrium, visualization of placenta within or outside the myometrium, direct invasion of pelvic structures by placental tissue as well as other specific features like T2W dark intraplacental bands, placental heterogeneity, bulging of uterine contour, and tenting of the urinary bladder [14,30,32]. Lax et al found uterine bulging, heterogeneous placental signal, and T2W dark intraplacental bands to be most useful, while Alamo et al found dark bands followed by interrupted myometrial border, pelvic organ invasion, and tenting of urinary bladder to be useful [14,28]. Meta-analysis by Familiari et al found IPDBs to be the most sensitive feature for the diagnosis of PAD, while specificity was moderate.[33] Bulging of the external uterine contour has been found to be predictive of placenta increta and percreta with excellent accuracy when used in conjunction with other signs.[34] The recently described joint SAR/ESUR guidelines suggest evaluation of the following seven MRI features that are categorized as "recommended" for diagnosing PAS disorders (with respective accuracies based on expert opinion, mentioned in parenthesis)—T2 dark intraplacental bands (90%), placental/uterine bulge (100%), loss of interface (90%), myometrial thinning (90%), bladder wall interruption (100%), focal exophytic mass (95%), and abnormal vascularization of placenta (100%). Uncertain findings include placental heterogeneity (70%), asymmetric shape of placenta (50%), ischemic infarction (60%), and abnormal intraplacental vascularity (70%).[26]

We found IPDBs to be the most consistently seen feature in the proven cases of PAD with 100% sensitivity, moderate specificity of 50%, and accuracy of 83.3%. These bands have irregular margins and the diameter can range from 6 to 20 mm. The IPDBs represent fibrin deposition as a consequence of repetitive intraplacental hemorrhage or infarcts. Studies have shown that the presence of IPDB is a predictor of poor maternal outcome and also that increasing volumes of IPDB correlate with the depth of invasion.[22,35] As per the meta-analysis by Familiari et al, comprising of 20 studies including 1,080 pregnancies, the presence of IPDB was the most sensitive MRI feature for the diagnosis of PAD with corresponding values of 89.7, 89.7, and 82.6% for placenta accreta, increta, increta, and percreta, respectively. The specificity was, however, moderate ranging between 49.5 and 58.5% for these categories.[33]

Placental heterogeneity (sensitivity: 75%, specificity: 75%), uterine contour abnormality (sensitivity: 75%, specificity: 87.5%), and myometrial thinning with loss of interface with myometrium (sensitivity: 100%, specificity: 37.5%) were the other features that aided in diagnosis assuming statistical significance in our study. Myometrial thinning to less than 2 mm along with loss of retroplacental dark line was used in conjunction to diagnose placental invasion to improve overall diagnostic accuracy that turned out to be significant in concordance with the aforementioned

Table 2 Utility of different MRI signs as predictors of PAD

MRI features	PAD ($n = 16$)	Nonadherent placenta ($n = 8$)	*p*-Value	Sensitivity %	Specificity %	PPV %	NPV %	Accuracy %
Intra-placental dark bands	16	4	0.007	100	50	80	100	83.3
Heterogeneous placenta	12	2	0.032	75	75	85.7	60	75
Thinned myometrial zone	16	5	0.028	100	37.5	76.2	100	79.2
Uterine contour abnormality	12	1	0.008	75	87.5	92.3	63.6	79.2
Shaggy external contour	4	0	0.262	100	40	25	100	50
Extrauterine placental invasion	5	1	0.621	31.25	87.5	83.3	38.8	50

Abbreviations: MRI, magnetic resonance imaging; NPV, negative predictive value; PAD, placental adhesive disorder; PPV, positive predictive value.

SAR/ESUR observations.[26] EUPI was diagnosed when there were direct indications of the same like bladder wall interruption, tenting of the bladder, invasion of other pelvic organs, and focal exophytic mass in the parametrium. EUPI was not a specific sign when used to detect the entire spectrum of PAD; however, it is useful in placenta percreta alone (sensitivity: 66.7%, specificity: 81%, PPV: 33.3%, NPV: 94.4%, accuracy: 79.2%).

It has been shown that the interobserver agreement in detecting placental heterogeneity, uterine contour abnormality, and myometrial invasion is poor relative to dark intraplacental bands, as the interpretation in MRI is dependent on the expertise of the radiologists.[16,26] Myometrial thinning can also normally occur in late gestation thereby contributing to low specificity of this sign when used independently. Hence, IPDB may be the most accurately identifiable feature in PAD. This is in concordance with other studies that have shown similar results.[14,16,28,29]

The intraoperative and postoperative outcomes of patients with PAD are influenced by accurate anatomical delineation and degree of placental invasion.[35] Naturally, placenta accreta and parametrial invasion are associated with worse outcomes, and this knowledge will help the obstetricians to decide the treatment strategy. Differentiating between the three subtypes on MRI is often difficult with a relatively lower and varying sensitivity, as has been noted in this study. Finally, the clinical grading during surgery together with pathology is used in making the differentiation between the categories as per The International Federation of Gynecology and Obstetrics (FIGO) guidelines.[36] Hence, this a potential pitfall of MRI and there is scope for further research in this area that needs to be explored in larger studies.

Limitations

There are some limitations in our study, foremost is the retrospective nature of analysis. Although the sample size is similar to other such studies, it does not comprise a large number. In view of small numbers in the various subgroups of the variables assessed, a multivariate regression analysis could not be performed. Ultrasonographic findings were not available due to institutional practices, which may have been present if the study was a prospective one. Histopathology was not available as a consistent reference standard in all cases as some patients with PAD did not require a hysterectomy ($n = 4$). The final diagnosis in these instances was based on intraoperative findings. Finally, the value of DWI could not be evaluated due to nonavailability in this retrospective analysis. DWI has been shown to be useful in confirmation of dark placental bands due to apparent "blooming" on this sequence.[16]

Conclusion

In conclusion, considering the rising incidence of PAD, radiologists need to be aware of this entity and its imaging features in routine antenatal evaluations. MRI has excellent sensitivity and good accuracy in the evaluation of high-risk patients, having a complimentary role to ultrasonography in diagnosing PAD. Recognition of risk factors and careful assessment of specific imaging features—especially low signal intensity bands in conjunction with loss of placental-myometrial interface, placental heterogeneity, and contour abnormality will allow the radiologists in making an accurate diagnosis, thereby aiding in preoperative planning and improvement of patient outcomes.

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Conflict of Interest
None declared.

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