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Original Article

Radiology Section

Emerging Role of Prenatal Magnetic Resonance Imaging in the Diagnosis of Placental Adhesion Disorders and its Relation with Intraoperative Findings- A Cross-sectional Study

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ABSTRACT

Introduction: Placental Adhesion Disorders (PADs) aka Placenta Accreta Spectrum (PAS) of disorders are a common cause of postpartum haemorrhage, which in turn is an avoidable cause of significant maternal morbidity and mortality. The exponential increase in the prevalence of PADs worldwide primarily ascribed to increasing percentage of caesarean section deliveries therefore contributes significantly to potentially life-threatening obstetrical emergencies. Accurate prenatal diagnosis of PAD is hence fundamental for patient management and prognostication. Imaging plays an indispensable role in the antenatal diagnosis of PAD thereby translating to improved maternal outcomes.

Aim: To determine the diagnostic accuracy of prenatal Magnetic Resonance Imaging (MRI) in predicting abnormal invasive placentation and to associate MRI findings with intraoperative findings.

Materials and Methods: The present cross-sectional study was conducted between March 2019 to March 2020. Pregnant females with clinically and/or sonographically suspected PAD and having major risk factors of PAD {Lower Segment Caesarean Section (LSCS) in previous and placenta previa in present gestation} were subjected to dedicated placenta protocol MRI examination. The placental morphology, localisation and adhesion suggestive features were evaluated in detail. Descriptive statistical analysis was done for final assessment.

Results: A total of 27 study participants, with mean age of 28±2.15 years, showed MRI findings compatible with PAD. Placenta previa complete (66.67%); was the dominant subtype observed in the study. In terms of degree of invasion, placenta accreta in 44.44% (n=12) was predominantly observed on preliminary MRI based assessment. The most reliable MRI features predictive of placental invasion in the present study (seen in 100% cases of PAD) included T2 dark intraplacental bands, heterogenous intraplacental signal intensity, disorganised intraplacental vascularity, myometrial thinning, loss of the uteroplacental interface and maternal neovascularity. In one case, MRI erroneously over-diagnosed increta as percreta. The overall diagnostic performance of these MRI parameters was with sensitivity, specificity, Positive Predictive Value (PPV) and Negative Predictive Value (NPV) of 100%, 95%; 87.5% and 100% in those with placenta percreta compared to 94.12%, 100.00%, 100% and 95% for the placenta accreta or increta cases, respectively.

Conclusion: MRI has high diagnostic accuracy in detection of PADs among the high-risk patients. Dedicated placenta protocol prenatal MRI should hence be incorporated in diagnostic work-up of all high-risk patients of PAD for reaping benefits of timely management, planning and saving lives.

Keywords: Accreta, Increta, Morbidly adherent placenta, Percreta

INTRODUCTION

Placental Adhesion Disorders (PAD) occur due to a defect in the decidua basalis which allows the invasion of chorionic villi into the myometrium [1,2]. It is classified on the basis of depth of myometrial invasion categorised as shown [Table/Fig-1] [3,4].

Classification	Depth of invasion
Placenta accreta vera	Villi are attached to the myometrium but do not invade the muscle
Placenta increta	Villi partially invade the myometrium
Placenta percreta	Villi invade up to or beyond the uterine serosa

[Table/Fig-1]: Classification of Placental Adhesion Disorders (PAD).

PAD is a significant cause of maternal morbidity and mortality and the most common indication for emergent postpartum hysterectomy in the present times [3,5-7]. It is a clinical and diagnostic challenge being encountered with increasing frequency due to ever increasing percentage of women undergoing primary and repeat caesarean sections [3,8-15]. Placenta previa and prior caesarean section are the two major risk factors for developing PAD with probability ranging from 3% in those with placenta previa alone to 24% in those with placenta previa and one prior caesarean delivery [1]. Also, noteworthy is the fact that this risk compounds with the number of previous caesarean section procedures to about 40% in those with previous two to 61% in those with previous three and 67% in those with four or more caesarean section deliveries [10,16-21]. The additional but relatively minor risk factors include advanced maternal age, uterine anomalies and previous uterine surgical interventions (dilatation and curettage, myomectomy and previous uterine surgery) [10,22].

Several studies have shown that PAD remain undiagnosed during pregnancy in upto half of all patients [23-25]. Due to the risk of life-threatening postpartum haemorrhage, rapid haemostasis is the cornerstone of management in these cases [25]. Prenatal diagnosis is hence crucial for planning the timing and site of delivery, availability of blood products and recruitment of a multidisciplinary team with expertise in high-risk obstetrics (gynaecologic surgeon, urologist, interventional radiologist and obstetric anaesthetist) to reduce maternal morbidity and mortality [13,14,26,27].

MRI is a problem-solving technique in placental evaluation if ultrasound evaluation is insufficient or confusing. Placenta evaluation

has been done in MRI obstetric imaging done for other indications also. The present study aimed to determine the diagnostic accuracy of prenatal MRI in predicting abnormal invasive placentation and to correlate MRI findings with intraoperative findings.

MATERIALS AND METHODS

This was a cross-sectional study conducted jointly by the Departments of Radiodiagnosis and Obstetrics and Gynaecology, Government Medical College and Rajindra Hospital, Patiala, Punjab, India. The study was of one year duration (March 2019 to March 2020) and was conducted after obtaining approval of the Institutional Research and Ethics Committee (vide letter No.TRG.9(310)2019/2235 dated March 6, 2019).

Inclusion criteria: A total of 35 consenting pregnant females (ongoing singleton gestation) with clinically suspected PAD and having major risk factors of PAD (LSCS in previous and/or placenta previa in present gestation) who reported during the study period were enrolled in the study.

Exclusion criteria: All those who did not give informed consent, had contraindications to MRI per se, were severely claustrophobic, had prior diagnosed placental pathology in present gestation or were lost on follow-up were excluded from the study. Postnatal cases with placental adherence were also excluded from the present study.

Study Procedure

MRI was performed on 1.5 Tesla (T) platform (SIEMENS MAGNETOM-Aera, SIEMENS Medical Systems, Erlangen, Germany) using a multichannel phased array body coil and "head-first" approach. The "feet-first" approach was followed in exceptional cases with severe claustrophobia. The mother was positioned in the supine or left lateral posture (the latter in cases of advanced gestation to avoid caval compression by the gravid uterus). No maternal sedation, intravenous paramagnetic contrast administration or oxygen supplementation was used in any case. A moderate level of urinary bladder distension was ensured prior to the commencement of the scan both to ensure patient comfort as well as to avoid under or overdistension, which could potentially hamper bladder invasion assessment. In all cases, sequences were acquired during maternal breath holding. The entire MRI examination was carried out under direct supervision of the reporting radiologist so as to ensure optimal image acquisition (repeat/additional planes wherever indicated) and subsequent accurate image interpretation.

MRI protocol: Dedicated placenta protocol MRI sequences were acquired using standard parameters as follows:

1. Three plane localisers of the maternal anatomy.
2. T2-weighted Half-Fourier Acquisition Single-shot Turbo spin-echo (HASTE) in all three orthogonal planes (axial, sagittal and coronal) relative to the gravid uterus.
3. True Fast Imaging with Steady-State Free Precession (TRUFI) in sagittal and coronal planes.
4. T1-weighted Volumetric Interpolated Breath-hold Examination (VIBE) sequences.
5. Additional images in planes perpendicular to the placenta-myometrium or myometrium-bladder interface on case-to-case basis.

Alternate interleaved slices were acquired to reduce cross-talk while planning sequences with thinner or contiguous slices. Sequences were repeated when the image quality was degraded by foetal motion or maternal respiratory-motion induced artifacts.

MRI image interpretation and analysis: Image stacks were transferred to advanced workstation and interpretation was done by a radiologist with 17 years of experience in female pelvic imaging who was blinded to the clinical history and antenatal ultrasound. The placental morphology, localisation and adhesion suggestive features were evaluated in detail on a dedicated MRI workstation in all cases. The diagnosis was confirmed in all cases by intraoperative findings and/or relevant histopathological correlation. Intraoperative and/or pathologic findings were the standard of reference.

STATISTICAL ANALYSIS

The data was collected and analysed using Epi-info (CDC, Atlanta) version 7.2.4. Descriptive statistical analysis was done for final assessment.

RESULTS

There were a total 35 consenting participants, among them 27 with mean age of 28 years±2.15 years had placental adhesions disorders and were analysed in the study. The youngest member was 24 years and oldest was 31 years of age. The gestation age at MRI examination ranged from 17 weeks to 37 weeks. The gravida status of the mothers varied from one to four while the parity ranged from zero (primigravida) to three in number [Table/Fig-2].

Parameter	Mean	SD	Range
Maternal age (in years)	28	2.15	24 to 31
Gravida	2.89	0.93	1 to 4
Parity	1.74	0.81	0 to 3
Gestational age (in weeks) at the time of MRI scan	30.10	6.27	17 to 37
Gestational age (in weeks) at the time of delivery/ surgical intervention	34.46	6.09	18 to 39
Number of prior LSCS	1.88	0.781	1 to 3

[Table/Fig-2]: Demographic and clinical characteristics of confirmed cases of Placental Adhesion Disorders (PAD).
SD: Standard deviation; LSCS: Lower segment caesarean section

After being diagnosed with PAD, 15 patients (55.56%) underwent complete hysterectomy of which 10 patients (37.04%) had prior bilateral internal iliac artery and uterine artery ligation; while the remaining 12 out of the total 27 patients (44.44%) underwent LSCS [Table/Fig-3].

Management	Frequency	Percentage (%)	Exact 95% LCL	Exact 95% UCL
CH	2	7.41	0.91	24.29
CH with partial cystectomy	1	3.70	0.09	18.97
CH with prior bilateral IAL and UAL	10	37.04	19.40	57.63
CH with prior UAE	2	7.41	0.91	24.29
Elective LSCS	4	14.81	4.19	33.73
Elective LSCS with bilateral tubal ligation	8	29.63	13.75	50.18
Total	27#	100		

[Table/Fig-3]: Management protocol for confirmed cases of PAD.
CH: Caesarean hysterectomy; IAL: Internal iliac artery ligation; UAL: Uterine artery ligation; UAE: Uterine artery embolisation; LSCS: Lower segment caesarean section; LCL: Lower confidence limits; UCL: Upper confidence limits; #Out of 35 Participants 27 had PAD

Significant morbidity was seen as postoperative ureteral injury related complications in 7.41% (n=2), infection in 29.63% (n=8) and persistent postpartum haemorrhage for three months partum period in 3.7% (n=1) cases. 7.41% cases (n=2) had increased need for blood products as more than 10 units in the intraoperative setting while maternal death due to excessive uncontrolled intra and immediate postoperative haemorrhage was seen in 3.7% (n=1). No case of uterine rupture was seen [Table/Fig-4].

Blood products used during treatment was nil in 29.64% (n=8) cases, 3 units in 22.22% (n=6), 4 in 14.81% (n=4), 6 in 11.11% (n=3), 7 in 14.81% (n=4) and more than 10 units in 7.41% (n=2) cases, respectively. Majority of cases (62.96%) were referred to a higher institute.

MRI parameters: In the present study, majority of cases had placental bulk located anteriorly; (59.26%) and 66.67% had grade 4 placenta previa. T2 dark intraplacental bands, heterogenous intraplacental signal intensity, disorganised intraplacental vascularity, myometrial thinning,

Complications*	Frequency	Percentage (%)	Exact 95% LCL	Exact 95% UCL
Blood transfusion >10 units	2	7.41	0.91	24.29
Ureteral ligation/Fistula	2	7.41	0.91	24.29
Infection	8	29.63	13.75	50.18
Perinatal death	2	7.41	0.91	24.29
Maternal death	1	3.70	0.09	18.97
Persistent postpartum haemorrhage >3 months	1	3.70	0.09	18.97
Referral to higher institute	17	62.96	42.37	80.60

[Table/Fig-4]: Clinical outcomes and complications for confirmed cases of PAD in present study.
*Some patients had more than one complication.

loss of the uteroplacental interface and maternal neovascularity were present in all the study subjects. In terms of degree of invasion, placenta accreta was the predominant finding observed in 44.44% (n=12) cases on preliminary MRI based assessment [Table/Fig-5a-c].

Variables	Frequency	Percentage (%)	Exact 95% LCL	Exact 95% UCL
Placental bulk				
Anterior	16	59.26	38.80	77.61
Central	2	7.41	0.91	24.29
Posterior	9	33.33	16.52	53.96
Degree of placenta previa				
1	4	14.81	4.19	33.73
2	4	14.81	4.19	33.73
3	1	3.70	0.09	18.97
4	18	66.67	46.04	83.48
T2 dark inter-placental bands	27	100	87.23	100
Heterogenous signal intensity	27	100	87.23	100
Placental bulge	25	92.59	75.71	99.09
Lumpy contour and rounded edges	21	77.78	57.74	91.38
Disorganised intraplacental vascularity	27	100	87.23	100
Maternal neovascularity	27	100	87.23	100
Placental-myometrial interface disruption	27	100	87.23	100
Myometrial thinning	27	100	87.23	100
Focal disruption of myometrium	13	48.15	28.67	68.05
Extra-uterine invasion				
Disruption of normal T2 hypointense bladder wall signal	9	33.33	16.52	53.96
Frank intra-vesical component	1	3.70	0.09	18.97
Placental cervical protrusion sign	1	3.70	0.09	18.97
Parametrial extension of placental tissue	0	-	-	-
Involvement of intrapelvic structures besides bladder	0	-	-	-

[Table/Fig-5a]: MRI parameters in confirmed cases of PAD*.
*Demonstrated in [Tables/Fig-6-10]

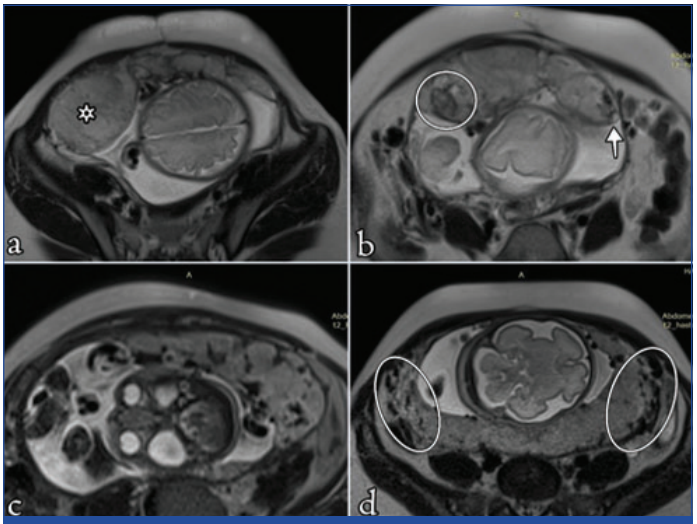
In the present study, MRI was able to detect even subtle focal myometrial disruption at prior LSCS scar site, whenever present, with 100% intraoperative concordance. The various clinical and demographic characteristics of the study population showed no statistically significant difference with management and MRI findings. Few images from the archives are shown in [Table/Fig-6-10].

Degree of invasion	MRI		Intraoperative findings and/or histopathology	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Accreta	12	44.44	14	51.85
Increta	4	14.81	6	22.22
Percreta	9	33.33	7	25.93
Suspicion of abnormal invasive placentation	2	7.41	0	0
Total	27	100	27	100

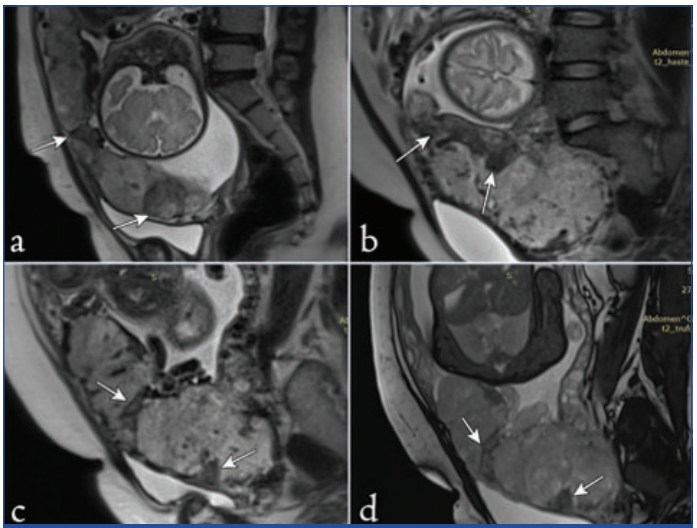
[Table/Fig-5b]: Degree of invasion-wise distribution of PAD.

Diagnostic utility parameters	Percentage (%)	Accreta/Increta (%)
Sensitivity	100	94.12
Specificity	95	100
Positive predictive value	87.50	100
Negative predictive value	100	95
Sensitivity+Specificity	1.950	1.941
Accuracy	96.30	97.22
Youden index	95	94.12
Kappa	90.78	94.41

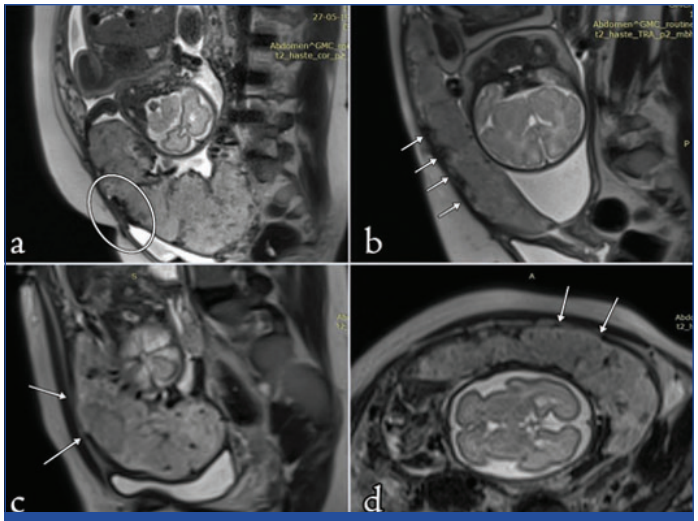
[Table/Fig-5c]: Diagnostic utility of MRI parameters.



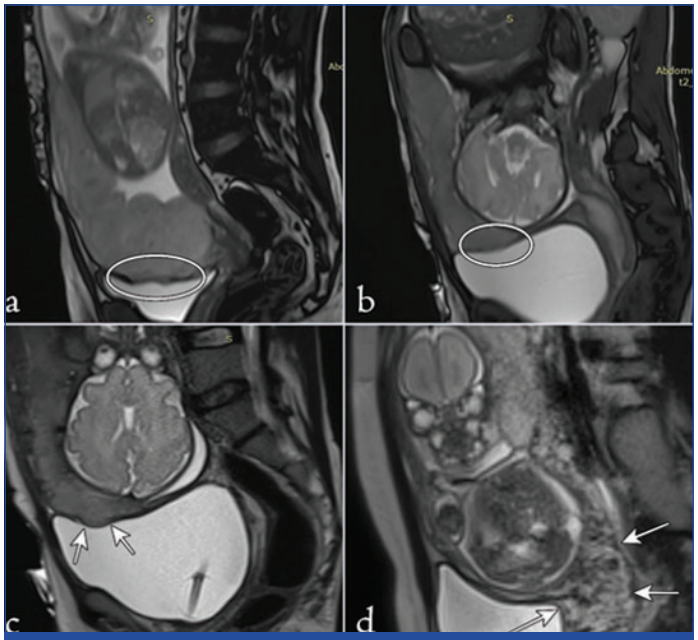
[Table/Fig-6a-d]: Axial T2 HASTE images (a) and (b) showing lumpy placental contour (star in 1a) and rounded placental edges (arrow in b). Note the associated presence of dark intraplacental band (white circle in b). Axial T2 HASTE images (c) and (d) show heterogenous intraparenchymal signal intensity of placenta (1c) and increased vascularity at the placental-myometrial interface (white ellipses in d).



[Table/Fig-7a-d]: Sagittal T2 HASTE images (a to c) and Sagittal TRUFI image (d) demonstrating the irregularly shaped dark intraplacental bands of varying thickness (white arrows) along with features of placenta previa. Note that the conspicuity of placental bands is greater in T2 HASTE images (c) as compared to TRUFI images (d).



[Table/Fig-8a-d]: Sagittal T2 HASTE image (a) in a case of placenta percreta showing focal tethering with loss of fat planes between the placental tissue with anterior abdominal wall and bladder dome at the site of previous LSCS scar with tenting of bladder (white ellipse). Sagittal TRUFI image (b) in a different patient with PAD showing loss of placental-myometrial interface and ill-defined planes with abdominal wall musculature (white arrows). Sagittal T2 HASTE (c) and axial T2 HASTE image (d) show focal gap in the dark myometrial signal (between arrows) with outward protuberance of placental tissue.

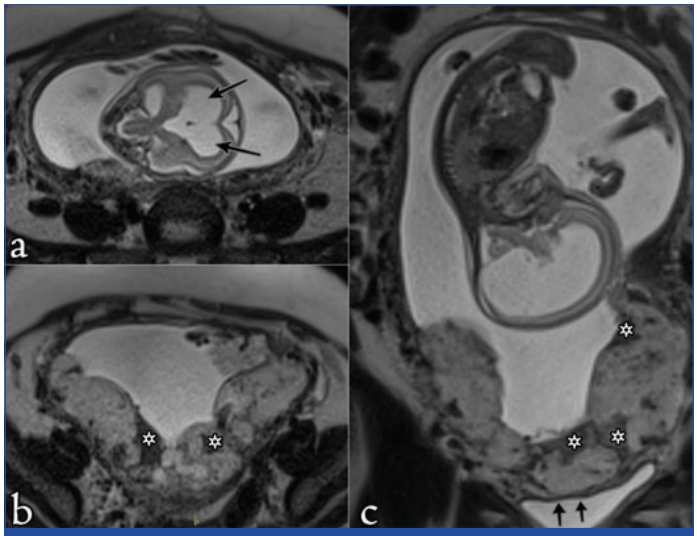


[Table/Fig-9a-d]: Sagittal TRUFI images (a and b) and Sagittal T2 HASTE image (c) in cases of placenta percreta showing small focal bulge with loss/blurring of low signal intensity interface between bladder and uterus (white ellipses in (a and b)) and white arrows in (c). Bladder invasion was confirmed at surgery. Sagittal T2 HASTE image (d) shows placenta previa with markedly heterogenous signal intensity of placental parenchyma which extends into the cervix suggestive of cervical invasion (white arrows).

DISCUSSION

The present study shows there was no statistical difference among the women in terms of maternal age, gestational age (at diagnosis and/or management), and the number of prior caesarean deliveries with management and MRI findings. This was in consonance with a similar study by Clark HR et al., who conducted a study among 64 females and reported no significant difference among the women in terms of maternal age, gestational age, or the number of prior caesarean deliveries to management [8].

The observations related to MRI parameters were in concurrence with some of the previously reported factors having higher generalisability as predictors of placental invasion including the presence of placental features (praevia, heterogeneous signal intensity with T2 hypointense bands, bulge, lumpy placental contour), placental-myometrial interface disruption, myometrial thinning and focal myometrial disruption similar to studies by several authors [28-33].



[Table/Fig-10a-c]: Foetal hydrocephalus with associated placentaincreta: Axial T2 HASTE images at level of foetal head (a), at level of pelvic inlet (b) and coronal T2 HASTE image (c) show evidence of foetal hydrocephalus (black arrows in a). The placenta shows complete previa with intraplacental bands (asterisks in b and c), marked placental heterogeneity and loss of interface with urinary bladder (black arrows in c) consistent with invasive placentation.

The present study reported a sensitivity of 100% and specificity of 95% for placenta percreta. Familiari A et al., conducted a meta-analysis on the utility of MRI in placenta evaluation reported a sensitivity of 86.5% and specificity 96.8% for placenta percreta [30]. The meta-analysis further concluded that of the different MRI signs intraplacental dark bands showed the best sensitivity for the detection of placenta accreta, increta and percreta; abnormal intraplacental vascularity, uterine bulging was associated with a higher risk of increta and percreta; exophytic mass and bladder tenting with placenta percreta. They however cautioned that although MRI has excellent diagnostic accuracy in identifying the depth and the topography of placental invasion but as it is used as a secondary imaging tool in women already screened for Abnormally Invasive Placenta (AIP) on ultrasound it might not reflect its actual diagnostic performance in detecting the severity of these disorders [30].

The present observations pertaining to extrauterine invasion were also similar to a study by Warshak CR et al., Bourgioti C et al., Masselli G et al., Kim JA et al., Leyendecker JR et al., Levine D and Levine D et al., [28,34-39]. In placenta percreta, loss of T2 hypointense bladder wall signal is the most reliable and specific sign [34,40] while intra-vesical extension/adjacent organ invasion is unreliable as it is witnessed less frequently. All cases with bladder wall signal disruption were peroperatively confirmed as percreta. However, there was one exception in which case MRI over-diagnosed it as percreta but was later confirmed as increta intraoperatively. Placental cervical protrusion sign [1] seen in 3.7% cases (n=1) was of particular significance in clinching the diagnosis of percreta.

Maternal neovascularity was observed in all PAD cases in the present study. Clark HR et al., also surmised that increased vascularity was the rule as expected from the multiparous population of women with placental implantation in the lower uterine segment with co-existent previa and observed that maternal vascularity does not have a significant association with placental invasion [8]. This finding was contradictory to findings in the established literature, which have described a correlation between increased vascularity and increased risk of invasion [30-33]. The variance could be due to its small sample being the confounding factor [8].

In the present study, the timely and accurate diagnosis enabled judicious management across all gestation ages (at time of diagnosis and management) and degrees of invasion in terms of referral to

higher obstetric emergency dedicated multidisciplinary institute in 62.96% (n=17), reduced need for caesarean hysterectomy in 44.44% (n=12) and favourable maternal outcomes in 96.3% (n=26) cases. In fact, no case of uterine rupture was recorded during the study which is otherwise a significant life-threatening complication of PAS. The clinical outcome was also favourable by way of healthy term babies in 92.59% (n=25) cases with perinatal mortality in only 7.41% (n=2) with both of the latter being preterm babies.

Another clinical outcome was the reduced need for blood products of more than 10 units in 7.41% cases only. This is likely ascribed to timely management including preoperative vascular intervention procedures (ligation or embolisation) carried out in a total of 44.45% (n=12) of all such PAS positive cases. Among these prior bilateral internal iliac and uterine arteries' ligation was carried out in 37.04% (n=10) cases and prior bilateral uterine artery embolisation procedures were performed in 7.41% (n=2) cases, respectively [Table/Fig-3]. Clark HR et al., showed significant blood requirement among patients who underwent hysterectomy [8].

Limitation(s)

Prospective studies in larger cohorts than the present study would enhance the diagnostic confidence based on MRI features alone, enabling quantitative evaluation of placental invasion and development of standardised multiple variable-based reporting templates. Being single observer-based study, analysis of inter-observer differences between at least two readers could not be done which is desirable for all future studies. High pretest probability for invasion due to selection bias targeting enhanced presence of PAS candidates; but this was intentional so as to increase the diagnostic yield. Lack of ultrasound correlation too was aimed at avoiding observer bias thereby emphasising the diagnostic utility of MRI from a complementary to a robust essential imaging modality in the work-up of suspected PAS cases.

CONCLUSION(S)

Prenatal MRI has high predictive accuracy in diagnosing disorders of invasive placentation among high-risk patients. At present ultrasound is the initial screening and diagnostic modality with MRI reserved for the sonographically inconclusive/incomplete cases due to modality related limitations per se, operator incompetence, maternal obesity and posterior placentation. However, the additional benefits of MRI in all cases include precise delineation of placental topography, depth of placental invasion and presence or absence of extra-uterine extension through defined features esp. T2 dark intraplacental bands, heterogenous intraplacental signal intensity, disorganised intraplacental vascularity, myometrial thinning, loss of the uteroplacental interface and maternal neovascularity- these factors in turn determine final surgical outcomes and also influence patient counselling in the context of fertility preservation options. Hence, it is recommended to incorporate dedicated placenta protocol prenatal MRI in the routine investigative work-up of all clinically suspected cases of PAD.

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