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ABDOMINAL IMAGING

ORIGINAL ARTICLE

The morbidly adherent placenta: when and what association of signs can improve MRI diagnosis? Our experience

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PURPOSE
We aimed to verify whether combination of specific signs improves magnetic resonance imaging (MRI) accuracy in morbidly adherent placenta (MAP).

METHODS
MRI findings for MAP were retrospectively evaluated in 27 women. Histopathology was the reference standard, showing MAP in eight of 27 cases. Specificity, sensitivity, positive predictive value, and negative predictive value were calculated for all MRI signs. Two skilled radiologists analyzed MRI findings, resolving discrepancies by consensus, using three alternative diagnostic criteria during three consecutive sections. First criterion: at least one of reported MRI signs indicates MAP and the absence of any sign is normal; second criterion: at least one statistically significant sign indicates MAP and no sign or nonsignificant sign is normal; third criterion: at least two statistically significant signs indicate MAP and no sign, nonsignificant sign, or only one significant sign is normal.

RESULTS
Using the first criterion yielded an unacceptable rate of false positive results (78.9%). Using the second criterion there were less false positive results (31.5%), and diagnostic accuracy of the second criterion was significantly higher than the first; the third criterion correctly classified 100% of cases.

CONCLUSION
Only specific MRI signs can correctly predict MAP at histopathology, particularly when multiple (at least two) specific signs are observed together.

Placenta is an organ responsible for nutritive, respiratory, and excretory functions of the fetus during pregnancy. An abnormal placentation into the uterine wall could present a risk of maternal and fetal morbidity (morbidly adherent placenta, MAP) and mortality, so it should be identified and defined early on (1, 2). In abnormal implantation, placental delivery fails, which can result in severe postpartum hemorrhage with possible multiple organ failure and damage to the nearby organs such as bladder, bowel, and ureters (3). In these cases, emergency hysterectomy is usually required. One-third to one-half of all emergency postpartum hysterectomies are performed as a result of adhesive placental disorders (4). MAP is classified on the basis of depth of infiltration into the myometrium: in placenta accreta, there is direct contact between chorionic villi and myometrium without decidua basalis; in placenta increta, chorionic villi invade the myometrium without reaching the serous layer; in placenta percreta, villi invade through the myometrium to reach or extend beyond the serosa into the surrounding tissues (5). The risk of placental abnormalities increases in the presence of uterine scars due to cesarean delivery or gynecologic procedures such as curettage, myomectomy, and hysteroplasty (when placenta implants are on the scar area), and also in women with maternal age greater than 35 years and multiparity. Previous cesarean delivery increases this risk to 3% for the first delivery, and to 40% and 67% for the third and fifth deliveries, respectively (4, 6). The site of placental implantation is a risk factor as well. Placenta previa is a pathologic condition in which the placenta is inserted in the lower uterine segment; it has been shown to be poorly developed during partum, contributing to postpartum hemorrhage (4). Prenatal ultrasonography (US) represents the first-line method for diagnosing antepartum placental abnormalities, with high sensitivity and specificity rates reported at 85.7% and 88.6%, respectively (7). However, examina-

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tion of posterior and distal portions of the placenta could be difficult to assess by US, and diagnostic results may depend on the US operator experience. In the antepartum period, magnetic resonance imaging (MRI) is requested to investigate placental disorders, particularly in difficult or ambiguous US examination cases. Specific diagnostic signs of abnormal placental implant on MRI pictures are reported in the literature (8–10). However, the final diagnosis of MAP is made based on the pathologic specimen obtained after hysterectomy, even if clinical signs such as the uterus continuing to bleed despite contraction could suggest MAP at cesarean section.

The first aim of this study was to assess the diagnostic performance of reported MRI signs in MAP diagnosis using histopathology as the reference standard. The second aim was to investigate whether MAP diagnosis can be improved using the reported MRI signs.

Methods

Study population and design

The Institutional Review Board approved this retrospective study and granted a waiver of informed consent. This study was conducted by re-evaluating MRI examinations of pregnant women who underwent MRI for suspicion of MAP after a doubtful or difficult US examination. The research was performed using our institutional RIS-PACS system (Radiologic informatics system: Imagoweb-El.Co.S.r.l.; Picture archiving and communication systems: Carestream Health). The filters included: interval time, 2011–2015; technique, MRI; UDC (cost diagnostic unit), gynecology; ULD (hospital logistic unit), obstetric pathology unit. MRI data were evaluated by two skilled radiologists with 10 years of expertise in gynecologic imaging, who reviewed and assessed the reported MRI signs for MAP diagnosis and resolved interpretation discrepancies by consensus. These two radiologists were blinded to clinical findings and the final diagnosis but were aware of patient's outcome. A third radiologist investigated medical records regarding cesarean section data and patient's outcome. The same third radiologist correlated imaging data with histopathogy in case of hysterectomy and gave to the examining radiologists the list of patients and signs to evaluate. The reference standard was histopathology (i.e., pathologic specimens after hysterectomy following the cesarean section). Patients who did not need hysterectomy because of noted clinical signs of physiologic placentation were considered normal. Inclusion criteria were: a) patients who underwent hysterectomy after cesarean section because of difficult placental separation after delivery and b) patients who did not need hysterectomy and showed clinical signs of physiologic placentation. Clinical signs of physiologic placentation are first obvious at the extraction, since the placenta comes out of the uterus quite easily without excessive traction and the inner uterine wall stops bleeding as soon as it starts to contract. In addition, during direct examination of the placenta, a normal placenta appears without any continuous solution on the uterine side, and there should be no bleeding, which means that placenta is complete and completely detached. Patients showing a difficult placental separation not undergoing hysterectomy were excluded from the study to avoid bias, since difficult placental separation has been described also in the presence of functional factors such as uterine atony or localized spasms (11, 12). Finally, 31 pregnant women were studied by MRI for suspected MAP after doubtful or difficult US examination between April 2011 and November 2015, with MRI examination performed between the 26th and 37th gestational weeks +5 days. Four patients who showed difficult placental separation after delivery but did not undergo hysterectomy were excluded from the study. Therefore, our study population included 27 pregnant women, 24 of 27 showing placental implant in the lower uterine segment (i.e., placenta previa).

Main points

- Placental disorders are usually investigated by ultrasonography (US). However, specific magnetic resonance imaging (MRI) signs can help the diagnosis in doubtful or inconclusive cases on US.
- Prepartum MRI can represent a problem-solving tool in patients with clinical risk factors of placental disorders or when the visualization of placenta is more challenging by US (posterior or caudal placenta). An accurate prepartum diagnosis assessed by MRI enables to stratify risk and plan cesarean section.
- MRI examination can be particularly useful to plan prophylactic treatments such as intravascular temporary balloon placement for bleeding control during hysterectomy.
- MRI findings should be analyzed carefully, since only specific signs are indicative of abnormal placentation and only presence of at least two of these signs can correctly diagnose the disease.

MRI technique

In our university, MRI examination for placental disorders is always performed by the same pool of radiologists with expertise in gynecologic imaging, using the same 1.5 T superconducting magnet (Vectra; GE Medical Systems). Our study protocol includes the supine decubitus with medium bladder distention to better assess potential bladder invasion and employment of multichannel surface coil, which maximizes the signal, providing a superior signal-to-noise ratio. Fast MRI sequences are usually suggested in the literature since they provide motion-free images of the abdomen in a limited time (2, 13). Examination time usually takes about 30 minutes. MRI examination is performed without using contrast media administration. Technical details of our protocol are summarized in Table 1.

MRI data and analysis

The reported MRI findings for MAP diagnosis included the following (Table 2):

1. Myometrial diameter ≤5 mm and loss of the trilaminate structure, or myometrial thinning (8);
2. Focally interrupted myometrial border (9);
3. Heterogeneous intraplacental signal, due to hemorrhage or vascular lacunae (9);
4. T2-weighted intraplacental dark thick bands, with longest diameter >2 cm (8);
5. Intraplacental abnormal vascularity: tortuous and enlarged flow voids observed on T2-weighted imaging deep within the placenta and measuring at least 6 mm in diameter (8);
6. Uterine bulging, which is defined as loss of normal "pear shape" of the uterus, with the fundus and the body wider than the caudal segments (8);
7. Direct visualization of invasion of the nearest tissues (10);
8. Tenting of the bladder, meaning that the bladder contour is pinched and stretched (10);
9. Placental protrusion into the internal os (8).

Statistical analysis

Results were analyzed by using 2×2 tables. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of MRI signs compared with histopathology were calculated for every single sign. Fisher exact test was used to

Table 1. MRI protocol in cases of suspicious placental abnormal implant

	FIESTA Axial	FIESTA Coronal/ Sagittal	T2W SS-FSE Axial oblique perpendicular to the uterine axis	T2W SS-FSE Coronal parallel to the uterine axis/ Sagittal	T2W SS-FSE fat sat Sagittal	T1W gradient echo Sagittal	T1W gradient echo fat-sat Sagittal
TR/TE (ms)	no/min full	no/min full	min/80	min/80	min/80	165/min	165/min
Flip angle	50	50	-	-	-	85	85
Field of view (cm)	44	48/44	44	44	44	44	44
Matrix	256×256	256×256	256×256	256×256	256×256	256×256	256×256
NEX	2	2	-	-	-	2	2
Depth (mm)	5	5	5	5	5	5	5
Intersection gap (mm)	0.5	0.5	0.5	0.5	0.5	0.5	0.5

FIESTA, fast imaging employing steady-state acquisition; T2W, T2-weighted; SS-FES, single-shot fast spin-echo fat-sat, fat-saturated; T1W, T1-weighted; TR, repetition time; TE, echo time; NEX, number of excitations.

Figure 1. a, b. MRI showing normal placenta in a 39-year-old woman at 36 weeks of gestational age. Sagittal **(a)** and axial **(b)** T2-weighted images show normal "pear shaped" uterus, with the placenta (P) extending to the edge of internal os *(arrow)* without covering it. The placenta is homogeneous with thin hypointense regular lines that represent septa. The three distinct layers of myometrium are visible, with the inner and outer layers showing as hypointense and the inner one showing as intermediate intensity *(arrowhead)*.

determine the statistical significance of each sign. MRI findings were evaluated in three separate and consecutive sessions using three different diagnostic criteria: first diagnostic criterion: the presence of at least any one of the reported MRI signs is considered an abnormal result and the absence of any sign is a normal result (Fig. 1); second diagnostic criterion: at least one statistically significant MRI sign is indicative of MAP diagnosis and no sign or statistically nonsignificant signs is a normal result; third diagnostic criterion: at least two statistically significant MRI signs is indicative of MAP diagnosis and no sign, or statistically nonsignificant signs, or only one statistically significant sign are indicative of normal placentation. The criteria were compared for diagnostic accuracy by the Exact McNemar test using histopathology as the reference standard. $P < 0.05$ was considered statistically significant.

Results

At cesarean section, 18 of 27 patients had no clinical evidence of placental invasion, while nine patients underwent hysterectomy because of difficult placental removal. Among these, eight cases showed MAP at histopathology, namely placenta accreta (n=5), placenta increta (n=2), and placenta percreta (n=1). One patient who underwent hysterectomy did not show any evidence of placental invasion at histopathology. In this case, hysterectomy was performed because of cervical bleeding related to massive periuterine adhesions. According to the first diagnostic criterion, which suggested MAP in the presence of at least one of the MRI signs listed above, MAP was diagnosed in 23 of 27 cases, showing 15 false positive and no false negative results (Table 3). Sensitivity, specificity, PPV, and NPV of MRI according to the first diagnostic criterion were 100%, 21.1%, 34.8%, and 100%, respectively ($P = 0.285$). Each sign was compared with the reference standard histopatology. Myometrial thinning sign was found in 23 of 27 patients (100% sensitivity, 21.1% specificity, 34.8% PPV, 100% NPV; $P = 0.285$). Heterogeneous intraplacental signal was seen in 16 patients (87.5% sensitivity, 52.6% specificity, 43.8% PPV, 90.9% NPV; $P = 0.090$). Focal interruption of myometrial border sign was found in 11 patients (100% sensitivity, 84.2% specificity, 72.7% PPV, 100% NPV; $P = 0.001$). Intraplacental abnormal vascularity sign was found in eight patients (75% sensitivity, 89.5% specificity, 85.7% PPV, 90% NPV; $P = 0.002$). Uterine bulging sign was found in eight patients (75% sensitivity, 94.7% specificity, 43.8% PPV, 90.9% NPV; $P = 0.001$). Tenting of the bladder sign was found in five patients (62.5% sensitivity, 100% specificity, 100% PPV, 86.4% NPV; $P = 0.001$). T2-weighted intraplacental dark thick bands sign was found in seven patients (87.5% sensitivity, 100% specificity, 100% PPV, 95% NPV; $P = 0.001$). Direct visualization of nearest tissues invasion was found in four patients (50% sensitivity, 100% specificity, 100% PPV, 82.6% NPV; $P = 0.004$). Placental protrusion in the internal os has never been detected in our series.

Among 19 normal cases comprising those with no clinical evidence of placental invasion (n=18) and the case with negative histopathology (n=1), six cases had only

Table 2. Characteristics of the study population

Pt. no	Age (yrs)	Risk factors and previous instrumental procedures			GA (weeks) at MRI exam	MRI signs									Histo-pathology
		CS	RUC	HSC		MT	FI	HS	DB	AV	UB	DI	TB	Total	
1	37	+ (n=1)	-	-	33	+	+	+	+	+	+	-	+	7	I
2	35	+ (n=3)	-	-	27	+	+	+	+	+	+	+	+	8	A
3	41	+ (n=4)	+ (n=2)	-	28+5 days	+	+	+	+	+	+	+	+	8	P
4	39	+ (n=1)	-	-	32+5 days	+	+	+	+	+	+	+	+	8	I
5	42	+ (n=1)	-	-	35	+	+	-	+	+	-	-	+	5	A
6	46	-	-	-	35	+	+	+	+	-	-	-	-	4	A
7	40	+ (n=3)	+ (n=1)	-	31	+	+	+	+	+	+	+	-	7	A
8	31	+ (n=2)	+ (n=3)	-	31	+	+	+	-	-	+	-	-	5	A
9	38	+ (n=1)	+ (n=1)	-	32	+	-	-	-	+	-	-	-	2	N
10	37	-	-	-	34	-	-	-	-	-	-	-	-	0	N/A
11	34	-	-	-	26	+	-	-	-	-	-	-	-	1	N/A
12	41	+ (n=2)	+ (n=1)	-	35+5 days	+	-	-	-	-	-	-	-	1	N/A
13	25	-	-	-	35+2 days	-	-	-	-	-	-	-	-	0	N/A
14	30	-	-	-	35+2 days	+	-	+	-	-	-	-	-	1	N/A
15	29	-	-	-	31	+	-	+	-	-	-	-	-	2	N/A
16	33	+ (n=1)	+ (n=1)	-	33	+	-	+	-	-	-	-	-	2	N/A
17	34	-	-	+ (n=1)	35	+	-	-	-	-	-	-	-	1	N/A
18	34	-	-	-	33	+	-	-	-	-	-	-	-	1	N/A
19	39	-	-	-	36	+	-	+	-	-	+	-	-	3	N/A
20	28	-	+ (n=1)	-	36	+	-	+	-	+	-	-	-	3	N/A
21	39	+ (n=1)	+ (n=1)	-	35+2 days	+	-	+	-	-	-	-	-	2	N/A
22	37	-	+ (n=1)	-	35	-	-	-	-	-	-	-	-	0	N/A
23	38	-	-	-	37+4 days	+	-	+	-	-	-	-	-	2	N/A
24	38	+ (n=3)	+ (n=2)	-	33	+	+	+	-	-	-	-	-	3	N/A
25	37	-	-	-	33	-	-	-	-	-	-	-	-	0	N/A
26	35	-	+ (n=2)	-	37+5 days	+	+	-	-	-	-	-	-	2	N/A
27	40	-	-	-	35	+	+	+	-	-	-	-	-	3	N/A

Pt., patient; CS, cesarean section; RUC, revision of uterine cavity; HSC, hysteroscopy; GA, gestational age; MT, myometrial thinning; FI, focal interruption of myometrial border; HS, heterogeneous signal; DB, T2-weighted dark intraplacental bands; AV, intraplacental abnormal vascularity; UB, uterine bulging; DI, direct visualization of tissue invasion; TB, tenting of the bladder; I, placenta increta; A, placenta accreta; P, placenta percreta; N, no signs at histopathology; N/A, histopathology not available (normal clinical findings).

Table 3. Performance of MAP diagnosis by MRI according to the first diagnostic criterion

	Histopathology positive	CS or histopathology negative	Total
MRI positive[a]	8	15	23
MRI negative[b]	0	4	4
Total	8	19	27

Sensitivity, 100%; specificity, 21.1%; positive predictive value, 34.8%; negative predictive value, 100%.
MAP, morbidly adherent placenta; MRI, magnetic resonance imaging; CS, cesarean section.
[a]At least one sign on MRI; [b]No sign on MRI.

one statistically significant sign, nine cases had nonsignificant signs, and four cases had no MRI sign (Table 2). Heterogeneous intraplacental signal was the most frequent nonsignificant sign observed in our series (n=16; 9/18 normal cases and 7/8 abnormal cases). Considering the presence of at least one statistically significant MRI sign as indicative of MAP diagnosis (i.e., the second diagnostic criterion), MRI sensitivity, specificity, PPV, and NPV were 100%, 68.4%, 57.1%, and 100% respectively (P = 0.002; Table 4). Coexistence of at least two statistically significant MRI signs (i.e., the third diagnostic criterion) increased sensitivity, specificity, NPV, and PPV of MRI to 100% for MAP diagnosis (P = 0.001; Table 5). Diagnostic accuracy of the second criterion was significantly higher than first criterion (78% vs. 44% of cases correctly classified; P = 0.004; Table 6). Number of incorrect diagnoses were insufficient to compare diagnostic accuracies of the second and third criteria.

Table 4. Performance of MAP diagnosis by MRI according to the second diagnostic criterion

	Histopathology positive	CS or histopathology negative	Total
MRI positive[a]	8	6	14
MRI negative[b]	0	13	13
Total	8	19	27

Sensitivity, 100%; specificity, 68.4%; positive predictive value, 57.1%; negative predictive value, 100%.
MAP, morbidly adherent placenta; MRI, magnetic resonance imaging; CS, cesarean section.
[a]At least one statistically significant sign on MRI; [b]No sign or statistically nonsignificant signs on MRI.

Table 5. Performance of MAP diagnosis by MRI according to the third diagnostic criterion

	Histopathology positive	CS or histopathology negative	Total
MRI positive[a]	8	0	8
MRI negative[b]	0	19	19
Total	8	19	27

Sensitivity, 100%; specificity, 100%; positive predictive value, 100%; negative predictive value, 100%.
MAP, morbidly adherent placenta; MRI, magnetic resonance imaging; CS, cesarean section.
[a]At least two statistically significant signs on MRI; [b]No sign, statistically nonsignificant signs, or only one statistically significant sign on MRI.

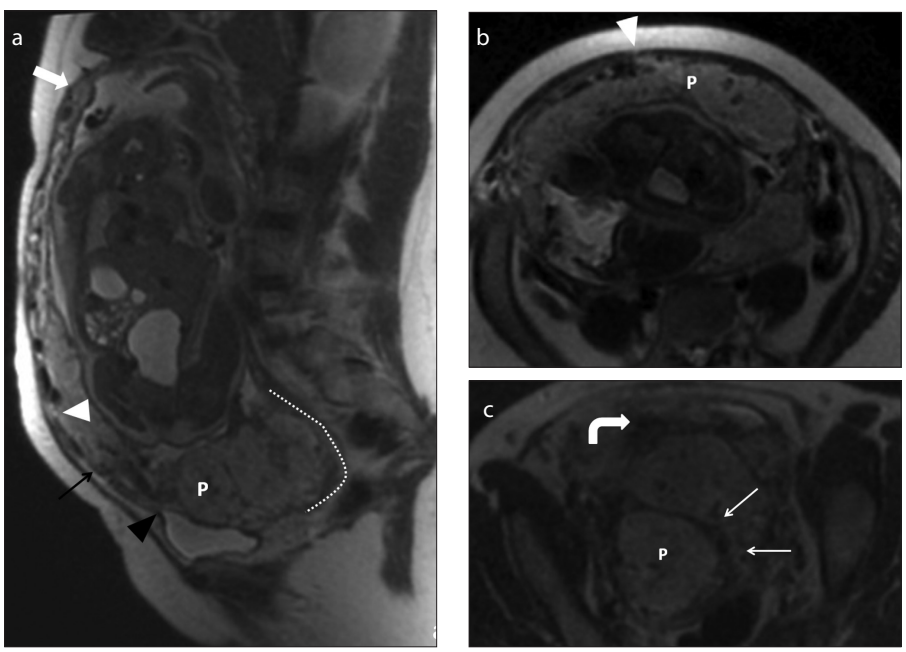

Figure 2. a–c. MRI in a 39-year-old woman at 32 weeks and 5 days of gestational age. Sagittal **(a)** and axial **(b)** T2-weighted MRI image taken perpendicularly to the long uterine axis show thinned myometrial border (myometrial thinning sign) with loss of the trilaminate structure of the myometrium (**a,** *thin black arrow*), which is focally interrupted (focal interruption sign) (**a** and **b,** *white arrowhead*). The normal trilaminate structure of the myometrium is seen cranially (**a**, *white arrow*). The upper contour of the bladder is also stretched and pinched (tenting of the bladder sign) (**a**, *black arrowhead*). The posterior contour of the uterus is bulged (uterine bulging sign) (**a**, *white line*). Axial T2-weighted image **(c)**, taken distally near the bladder, shows inhomogeneous signal intensity of the placenta with a vascular lacuna (heterogeneous signal sign) (**c**, *white curved arrow*) and intraplacental dark thick band (dark band sign) with longest diameter >2 cm (**c**, *white arrows*). The cesarean section was performed a week later and histopathology confirmed morbidly adherent placenta (MAP, placenta increta) at the anterior lower third of the uterus. P, placenta.

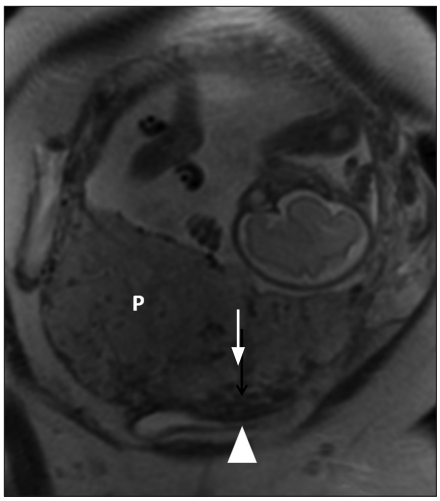

Figure 3. MRI in a 41-year-old woman at 28 weeks and 5 days of gestational age. The coronal oblique T2-weighted image shows tortuous and enlarged intraplacental flow voids (abnormal vascularity sign) well evident at the left anteroinferior side of the uterus *(arrow)*; the placenta seems to directly invade the vesicouterine space (direct visualization of the nearest tissue invasion sign, *arrowhead)*. Cesarean section was performed five days after MRI and histopathology after hysterectomy confirmed MAP (placenta percreta). P, placenta.

Discussion

Using the first diagnostic criterion, MRI was extremely sensitive but had very low specificity with an unacceptable rate of false positive results (78.9%), and was not statistically significant with respect to the histopathologic reference standard. This may be related to the different diagnostic accuracy of each sign. Using the second diagnostic criterion, MRI specificity increased significantly compared with the reference standard histopathology, and the number of false positive results decreased (31.5%). The third criterion correctly classified 100% of cases. This observation can help radiologists to correctly analyze MRI findings, since special attention should be paid in identifying particular signs that are more indicative for MAP than the others.

Ueno et al. (8) detected myometrial thinning (Fig. 2) in 80% of patients without clinical or histopatologic evidence of placental invasion. This sign seems to be frequently associated with normal pregnancies, particularly during the third trimester due to a bigger fetus (10).

A recent meta-analysis has shown 57.7%–90.8% sensitivity and 50.4%–98.0% specificity for heterogeneous intraplacental signal related to hemorrhage and vascular lacunae (7) (Fig. 2). However, Lax et al. (14) has detected this sign in patients with invasive placenta (10/10 patients) as well as in normal placenta (10/10), similar to our findings. It appears that only marked heterogeneity is related to placental invasion, while mild or moderate heterogeneity can be also found in normal placenta (14).

Focal interruption of myometrial border (Figs. 2 and 3) has shown 79.2%–97.2% sensitivity and 50.4%–90.4% specificity in the recent literature (7). Some authors

Table 6. Diagnostic accuracy of the second vs. first criterion in diagnosing MAP on MRI

		Diagnostic accuracy of the first criterion	
		Correct diagnoses	Incorrect diagnoses
Diagnostic accuracy of the second criterion	Correct diagnoses	12	9
	Incorrect diagnoses	0	6

Accuracy of the second and first MRI diagnostic criteria were determined by histopathology.
MAP, morbidly adherent placenta; MRI, magnetic resonance imaging.

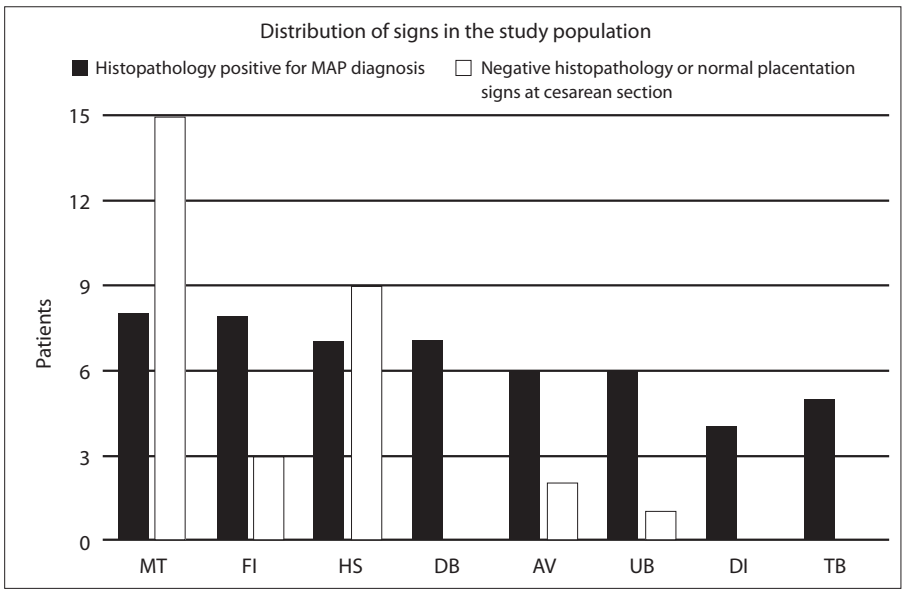

Figure 4. Bar chart showing distribution of MRI signs in the whole study population (i.e., cases with MAP diagnosis at histopathology and cases negative for MAP at histopathology and cesarean section). MT, myometrial thinning; FI, focal interruption of myometrial border; HS, heterogeneous signal; DB, T2-weighted dark intraplacental bands; AV, intraplacental abnormal vascularity; UB, uterine bulging; DI, direct visualization of nearest tissue invasion; TB, tenting of the bladder.

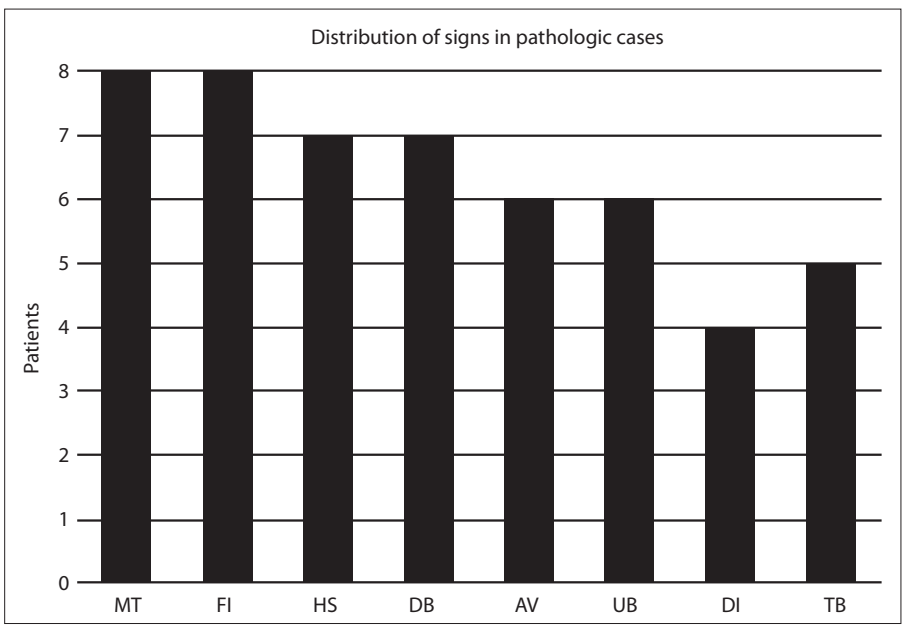

Figure 5. Bar chart showing distribution of MRI signs in the eight patients diagnosed with MAP at histopathology. MT, myometrial thinning; FI, focal interruption of myometrial border; HS, heterogeneous signal; DB, T2-weighted dark intraplacental bands; AV, intraplacental abnormal vascularity; UB, uterine bulging; DI, direct visualization of nearest tissue invasion; TB, tenting of the bladder.

retain that progressive myometrial thinning during the pregnancy could make focal interruptions undistinguishable and, therefore, they recommend performing MRI within the 35th gestational week to recognize focal interruption of myometrial border (9). In our study population, focal interruption sign was observed only in patients who underwent MRI within the 35th gestational week (Table 2).

Intraplacental abnormal vascularity (Fig. 3) has been described as a very accurate sign in the literature (8), while uterine bulging (Fig. 2) is still being discussed. Leyendecker et al. (4) reported uterine bulging sign to be one of the most specific MRI signs in placental invasion, considering as uterine bulging the placental tissue seen bulging outward, disrupting the smooth arc and distorting the outer contour of the uterus. D'Antonio et al. (7) reported 60.3%–90.4% sensitivity and 76.2%–96.4% specificity for uterine bulging sign.

In other studies, tenting of the bladder (Fig. 2) has been reported to have 28%–99.5% sensitivity and 28%–99.5% specificity (7); T2-weighted intraplacental dark thick bands (Fig. 2) has been reported to have 70.9%–95.6% sensitivity and 55.6%–84% specificity (13); and direct visualization of nearest tissues invasion sign (Figs. 2 and 3) has been reported to have 50% sensitivity and 100% specificity (9).

Thus, each MRI sign shows a different performance in diagnosing MAP, in our study as well as in others, and some signs are more frequently observed in MAP cases than in normal placentation (Fig. 4), being more frequently associated with pathologic cases (Fig. 5). According to our results, MRI accuracy in MAP diagnosis markedly improves by using only specific signs, particularly when multiple (at least two) specific signs are observed together. Uterine bulging and tenting of the bladder signs were both present in cases of deeper placental invasion (placenta increta and percreta; 3/8 of abnormal cases; Table 2), but the degree of deep infiltrative disease could not be always easily assessed, as also reported in other studies (15).

The reported sensitivity and specificity in MAP diagnosis for US is high, ranging between 77%–88% and 93%–96%, respectively (16). However, MRI allows a better examination than US in the evaluation of the posterior uterine wall and in the lower uterine portion. In the literature, the reported diagnostic performance of MRI is higher but

similar to US (i.e., 90% sensitivity and 88% specificity) (7). Our results suggest that MRI accuracy can further increase when specific signs are considered for the diagnosis. In addition, MRI examination is superior to US in soft tissue contrast and field of view (2) and can be useful in those cases where US can fail. MRI diagnosis of invasive placenta improves patient management at cesarean section, reducing both mother and fetus mortality and morbidity. In suspected cases, surgical team can be improved with a urologist, digestive surgeon, or interventional radiologist. Moreover, MAP diagnosis allows prophylactic temporary balloon occlusion of the internal iliac arteries, an interventional radiology technique for bleeding control in patients with placenta accreta during cesarean hysterectomy (17).

Many signs have been described in MRI evaluation for MAP diagnosis in previous reported studies in the literature usually using the clinical evidence at cesarean section as the reference standard. To our knowledge, only few studies based on clinical finding at delivery and pathologic examination of specimens have been previously reported in the evaluation of MRI signs for MAP diagnosis (18, 19). A recent work analyzing prenatal MRI in 28 females using the clinical findings (25/28 cases) or pathologic specimens (3/28 cases) as the reference standard previously noted that an association of characteristic signs strongly indicates placental invasion by MRI (19). The results of our study support that hypothesis and encourage antenatal evaluation by MRI in suspected cases of placental disorders.

We are aware that our study presents some limits. This is a retrospective study and our study series includes a small number of patients with few histopathologic examinations. By contrast, one of the advantages of this study is the homogeneity of the study population. We included all patients with suspected invasive placenta at US or those with a difficult US examination. All patients were referred by the same Obstetric Pathology Unit and were studied using the same study protocol. In addition, we used histopathology as the reference standard, which represents the best reference standard available for invasive placenta diagnosis since there is no chance of misdiagnosis. Limitations inherent to MRI technique include the duration-time of about 30 minutes, since the patient has to stay in the supine position and fetus can compress iliac veins blocking venous blood flow. However, to reduce this limitation, if necessary, the patient could stay in the lateral position. Expensiveness, low availability, and need of expertise are further limits of MRI. However, MRI technique can be easily repeated and is less operator dependent than US, although a dedicated team of radiologists is encouraged.

In conclusion, our results show that MRI signs demonstrate different diagnostic performances in predicting MAP confirmed at pathologic specimens. Only specific MRI signs can correctly predict MAP at histopathology, and the presence of at least two specific MRI signs is particularly useful. Larger study series would be helpful to validate our data, as MAP diagnosis could increase in the next years given the increased frequency of advanced maternal age and uterine surgery, and early diagnosis can effectively reduce placental invasion mortality and morbidity.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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