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Interobserver agreement in MRI assessment of severity of placenta accreta spectrum disorders

F. FINAZZO[1], F. D'ANTONIO[2,3], G. MASSELLI[4], F. FORLANI[5], J. PALACIOS-JARAQUEMADA[6], G. MINNECI[5], S. GAMBARINI[1], I. TIMOR-TRITSCH[7], F. PREFUMO[8], D. BUCA[9], M. LIBERATI[9], A. KHALIL[10,11] and G. CALI[5]

[1]*Radiology Department, Arnas Civico Hospital, Palermo, Italy;* [2]*Women's Health and Perinatology Research Group, Department of Clinical Medicine, Faculty of Health Sciences, UiT - The Arctic University of Norway, Tromsø, Norway;* [3]*Department of Obstetrics and Gynecology, University Hospital of Northern Norway, Tromsø, Norway;* [4]*Radiology Department, Sapienza University, Rome, Italy;* [5]*Department of Obstetrics and Gynaecology, Arnas Civico Hospital, Palermo, Italy;* [6]*Centre for Medical Education and Clinical Research (CEMIC), University Hospital, Buenos Aires, Argentina;* [7]*Department of Obstetrics and Gynecology, Division of Maternal-Fetal Medicine, New York University SOM, New York, NY, USA;* [8]*Department of Obstetrics and Gynecology, University of Brescia, Brescia, Italy;* [9]*Department of Obstetrics and Gynecology, University of Chieti, Chieti, Italy;* [10]*Fetal Medicine Unit, St George's University Hospitals NHS Foundation Trust, University of London, London, UK;* [11]*Vascular Biology Research Centre, Molecular and Clinical Sciences Research Institute, St George's University of London, London, UK*

KEYWORDS: interobserver variability; MRI; placenta accreta; placenta previa

CONTRIBUTION

What are the novel findings of this work?
Magnetic resonance imaging (MRI) has excellent interobserver agreement in identifying the presence and depth of placenta accreta spectrum disorders. Interobserver agreement is lower for assessment of the topography of invasion, especially for the detection of parametrial invasion and the presence of newly formed vessels within the parametrial tissue, which can significantly affect maternal outcome.

What are the clinical implications of this work?
There is an urgent need for an objective standardized system for MRI assessment of the topography of placental invasion, and for a reproducible MRI prenatal staging system aimed at stratifying the surgical risk of women affected by these anomalies.

ABSTRACT

Objective *To evaluate the level of agreement in the prenatal magnetic resonance imaging (MRI) assessment of the presence and severity of placenta accreta spectrum (PAS) disorders between examiners with expertise in the diagnosis and management of these conditions.*

Methods *This was a secondary analysis of a prospective study including women with placenta previa or low-lying placenta and at least one prior Cesarean delivery or uterine surgery, who underwent MRI assessment at a regional referral center for PAS disorders in Italy, between 2007 and 2017. The MRI scans were retrieved from the hospital electronic database and assessed by four examiners, who are considered to be experts in the diagnosis and surgical management of PAS disorders. The examiners were blinded to the ultrasound diagnosis, histopathological findings and clinical data of the patients. Each examiner was asked to assess 20 features on the MRI scans, including the presence, depth and topography of placental invasion. Depth of invasion was defined as the degree of adhesion and invasion of the placenta into the myometrium and uterine serosa (placenta accreta, increta or percreta) and the histopathological examination of the removed uterus was considered the reference standard. Topography of the placental invasion was defined as the site of placental invasion within the uterus in relation to the posterior bladder wall (posterior upper bladder wall and uterine body, posterior lower bladder wall and lower uterine segment and cervix or no visible bladder invasion) and the site of invasion at surgery was considered the reference standard. The degree of interrater agreement (IRA) was evaluated by calculating both the percentage of observed agreement among raters and the Fleiss kappa (κ) value.*

Results *Forty-six women were included in the study. The median gestational age at MRI was 33.8 (interquartile range, 33.1–34.0) weeks. A final diagnosis of placenta accreta, increta and percreta was made in 15.2%, 17.4% and 50.0% patients, respectively. There was excellent agreement between the four examiners in the assessment*

Correspondence to: Dr F. D'Antonio, Fetal Medicine Unit, Department of Medical and Surgical Sciences, Department of Obstetrics and Gynecology, University of Foggia, Viale L. Pinto, 71100 Foggia, Italy (e-mail: dantoniofra@gmail.com)

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of the overall presence of a PAS disorder (IRA, 92.1% (95% CI, 86.8–94.0%); κ, 0.90 (95% CI, 0.89–1.00)). However, there was significant heterogeneity in IRA when assessing the different MRI signs suggestive of a PAS disorder. There was excellent agreement between the examiners in the identification of the depth of placental invasion on MRI (IRA, 98.9% (95% CI, 96.8–100.0%); κ, 0.95 (95% CI, 0.89–1.00)). However, agreement in assessing the topography of placental invasion was only moderate (IRA, 72.8% (95% CI, 72.7–72.9%); κ, 0.56 (95% CI, 0.54–0.66)). More importantly, when assessing parametrial invasion, which is one of the most significant prognostic factors in women affected by PAS, the agreement was substantial and moderate in judging the presence of invasion in the coronal (IRA, 86.6% (95% CI, 86.5–86.7%); κ, 0.69 (95% CI, 0.59–0.71)) and axial (IRA, 78.6% (95% CI, 78.5–78.7%); κ, 0.56 (95% CI, 0.33–0.60)) planes, respectively. Likewise, interobserver agreement in judging the presence and the number of newly formed vessels in the parametrial tissue was moderate (IRA, 88.0% (95% CI, 88.0–88.1%); κ, 0.59 (95% CI, 0.45–0.68)) and fair (IRA, 66.7% (95% CI, 66.6–66.7%); κ, 0.22 (95% CI, 0.12–0.37)), respectively.

Conclusions *MRI has excellent interobserver agreement in detecting the presence and depth of placental invasion, while agreement between the examiners is lower when assessing the topography of invasion. The findings of this study highlight the need for a standardized MRI staging system for PAS disorders, in order to facilitate objective correlation between prenatal imaging, pregnancy outcome and surgical management of these patients.*

INTRODUCTION

Placenta accreta spectrum (PAS) disorders encompass a heterogeneous group of conditions characterized by progressive invasion of the trophoblastic tissue into the myometrium and uterine serosa[1–3]. The prenatal diagnosis of PAS disorders has been shown to reduce the risk of severe maternal morbidities, such as massive hemorrhage and the need for blood products, by allowing preplanned management in centers with high expertise in the surgical management of these anomalies[4].

Ultrasound is usually the primary imaging tool for assessing women at risk for a PAS disorder, such as those presenting with placenta previa and prior Cesarean delivery (CD) or uterine surgery, while magnetic resonance imaging (MRI) is performed to confirm the ultrasound diagnosis and delineate the depth and topography of placental invasion, which can significantly affect maternal outcome and influence the surgical approach[5–11].

Both ultrasound and MRI have been shown to have good overall diagnostic accuracy in detecting PAS disorders[6,7]. However, there is significant heterogeneity in the reported diagnostic performance of ultrasound and MRI for PAS disorders between individual studies, with some showing a high diagnostic accuracy and others a lower detection rate. Several factors, such as maternal characteristics, operators' experience and gestational age at assessment, are likely to account for such differences[6,7,9,10].

The large majority of previously published studies assessing the accuracy of ultrasound and MRI in diagnosing PAS disorders have focused on detecting the presence of such disorders (detection rate), without investigating the potential differences in assessing the radiological signs, such as the depth and site of placental invasion[6–9]. However, the latter features are fundamental, as the surgical outcome of women affected by a PAS disorder are directly related to the depth and especially the topography of placental invasion[12,13]. Furthermore, cases affected by the same degree of placental invasion may show different outcomes depending on the site of invasion[14].

The aim of this study was to assess the level of agreement in the MRI assessment of the presence and severity of PAS disorders between examiners with high expertise in the diagnosis and management of these conditions.

METHODS

This was a secondary analysis of a prospective study including women with placenta previa or low-lying placenta and at least one prior CD or uterine surgery, who underwent MRI assessment at the Department of Radiology, Arnas Civico Hospital, Palermo, Italy, a regional referral center for PAS disorders, between 2007 and 2017. All women underwent serial ultrasound assessment in the second and third trimesters, as per local guidelines, in order to evaluate the presence of a PAS disorder. All patients also underwent MRI evaluation in the third trimester in order to confirm the presence, depth and topography of placental invasion.

MRI scans were retrieved from the hospital's electronic database and were assessed by four examiners, including three radiologists (F.Fi., G.Ma., S.G.) and one surgeon (J.P.-J.), who are considered to be experts in the diagnosis and surgical management of PAS disorders, each having managed hundreds of cases at risk for such conditions. The examiners were blinded to the ultrasound diagnosis, histopathological findings and clinical data of the patients.

Each examiner was asked to judge the following features (Appendix S1, Figure 1): (1) presence of a PAS disorder; (2) depth of placental invasion (placenta accreta, increta or percreta); (3) topography of placental invasion in the sagittal plane (posterior upper bladder wall and uterine body, posterior lower bladder wall and lower uterine segment and cervix or no visible bladder invasion); (4) presence of parametrial invasion in the axial and coronal planes; (5) presence and number of newly formed vessels in the parametrial tissue, evaluated in the axial plane; (6) location of the placenta (anterior, posterior, lateral or fundal); (7) presence and type of placenta previa (the placenta was defined as 'placenta previa' when it was lying directly over the internal os and as 'low-lying'

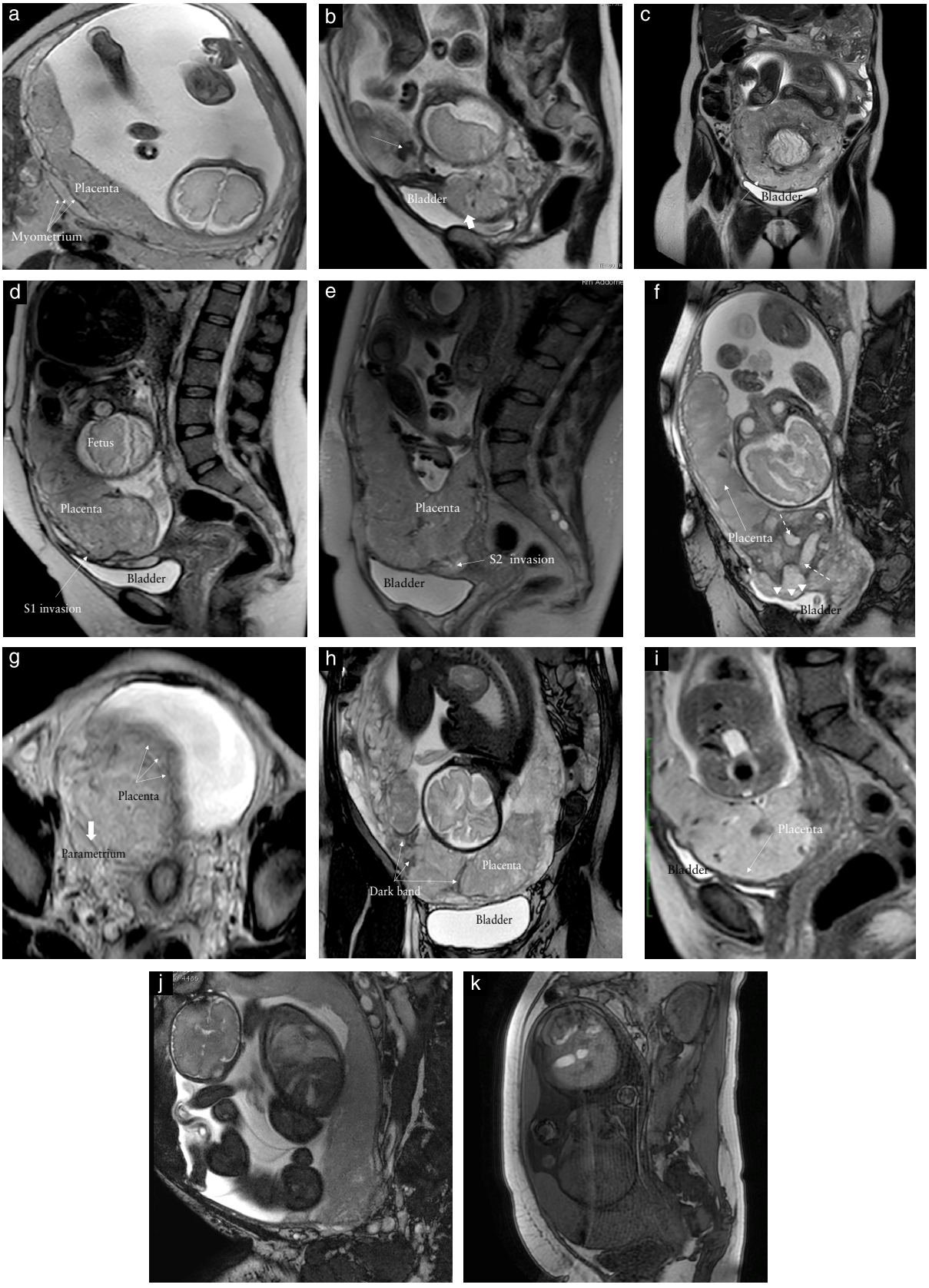

Figure 1 Magnetic resonance images showing: (a) normal placenta and three layers (arrows) of normal myometrium (hypointense outer and inner layers surround more hyperintense middle layer, which contains vessels); (b) presence of placenta percreta in S2 segment, intraplacental dark bands (thin arrow) and outward bulging of placenta (thick arrow); (c) presence of placenta accreta without bladder invasion (arrow points to uterus–bladder interface); (d) presence of placenta percreta with invasion of S1 segment; (e) presence of placenta percreta with invasion of S2 segment; (f) presence of intraplacental dark bands (dashed arrows) and bladder invasion (arrowheads); (g) presence of placenta percreta with bladder invasion (thin arrows) and newly formed vessels in parametrium (thick arrow); (h) presence of intraplacental dark bands (arrows) and heterogeneous signal within placenta; (i) focal outward bulging of placenta (arrow points to uterus–bladder interface); (j,k) artifacts due to fetal movements.

when it was located < 20 mm from the internal os[15]); (8) heterogeneous placental signal intensity, defined as heterogeneity in the placental parenchyma, which in normal conditions is characterized by a homogeneous intermediate signal intensity[16]; (9) presence and features of intraplacental dark bands, defined as nodular or linear areas of low signal intensity on T2-weighted images[16]; (10) presence of areas of hemorrhagic placental infarction; (11) presence, shape and number of placental venous lakes (lacunae); (12) characteristics of the uterus–bladder interface (visible myometrium, interrupted interface or not-infiltrated myometrium visible near the cervix); (13) presence and characteristics of uterus–bladder interface vascularization; (14) outward bulging of the placenta (i.e. widening of the lower uterine segment with consequent distortion of the normal inverted pear shape of the gravid uterus into an hourglass shape); (15) whether the bladder was filled; and (16) presence of artifacts.

The reference standard was the presence of a PAS disorder confirmed on histopathological assessment or, in the most severe types of invasion, on surgical evaluation. For the depth of placental invasion, the reference standard was histopathological examination of the removed uterus[17]. Placenta accreta was diagnosed when anchoring placental villi were attached to the myometrium rather than the decidua, but without completely invading it. Placenta increta was diagnosed when chorionic villi penetrated the myometrium, while placenta percreta was considered when chorionic villi penetrated through the myometrium into the uterine serosa or adjacent organs[17]. For assessment of the topography of placental invasion on MRI, we adopted the anatomical classification of PAS disorders proposed by Palacios-Jaraquemada *et al.*[12]. According to this, anterior placental invasion is divided into two sectors delimited by a plane perpendicular to the superior–inferior bladder axis; the posterior upper bladder wall and the bordering uterine sector is called S1, while the posterior lower bladder wall and the uterine sector adjacent to it is called S2 (Figure 2). From an anatomical perspective, S1 invasion refers to invasion of the uterine body while S2 is mainly located in the lower uterine segment or below it. The reference standard was the topography of invasion at surgery[12]. In women not undergoing hysterectomy, the presence of PAS disorders was defined according to the clinical grading system of the International Federation of Gynecology and Obstetrics[3]. Cases with no PAS disorder were defined as those with complete placental separation in the third stage of labor[3].

All uterine specimens were assessed by the same research pathologist, who was blinded to the prenatal imaging (ultrasound and MRI) and surgical findings. As different degrees of placental invasion may coexist in the same uterus, every case was labeled according to the maximum observed depth of placental invasion[18].

All MRI examinations were performed on a 1.5-Tesla (T) unit (Ingenia Philips Medical System, Amsterdam, The Netherlands) with body array coils, including axial, coronal and sagittal T2-weighted half-Fourier single-shot turbo spin echo (SSH-TSE) imaging or T2-weighted turbo spin echo (T2 W-TSE) and/or T2-weighted true fast imaging with steady-state precession sequence (balanced-FFE) and sagittal T1-weighted gradient-echo (T1 W-GRE) in-phase and opposed-phase sequence. The parameters for SSH-TSE images were: repetition time (TR)/echo time (TE), 3300–4000/70–80 ms; flip angle (FA), 90°; field of view (FOV), 420–480 mm; slice thickness, 5–8 mm. For balanced-FFE images they were: TR/TE, 3700–5400/60–90 ms; FA, 90°; FOV, 420–480 mm; slice thickness, 6–8 mm. For T1 W-GRE images they were: TR/TE, 200–230/2.3 (opposed phase)/4.6(in-phase) ms; FA, 80°; FOV, 340–380 mm; slice thickness, 5–8 mm. No contrast material was used in any of the examinations.

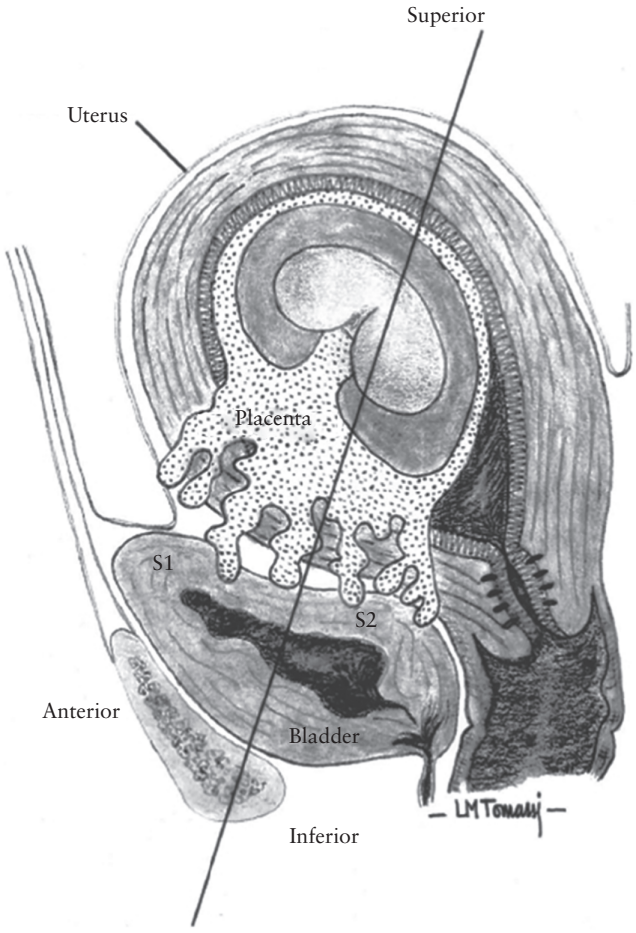

Figure 2 Classification of topography of placenta accreta spectrum disorders according to system proposed by Palacios-Jaraquemada *et al.*[12]. Anterior placental invasion is divided into two sectors delimited by plane perpendicular to superior–inferior bladder axis. Invasion of sector S1 involves posterior upper bladder wall and bordering uterine sector (uterine body). Invasion of sector S2 involves posterior lower bladder wall and uterine sector adjacent to it (lower uterine segment and cervix). (Reproduced from D'Antonio *et al.*[11]).

Statistical analysis

Continuous data are reported as median (interquartile range (IQR)). For each of the 20 items of the

questionnaire, we assessed the degree of interrater agreement (IRA), recording both the percentage of observed agreement among raters and the Fleiss kappa (κ), with 95% CIs[19–24]. Fleiss κ is an extension of Cohen's κ when more than two raters are present, and is obtained by comparing the observed agreement with the amount of agreement expected by chance[19,20]. According to Landis and Koch, κ values were interpreted as: < 0, poor agreement; 0.0–0.20, slight agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, substantial agreement; 0.81–1.0, almost perfect agreement[22]. We also calculated a summary κ coefficient for all items of the questionnaire, in order to quantify the overall agreement between raters. Sample size considerations were based upon the CIs of the interrater κ statistic, and the computations were performed using the kapssi command in Stata (StataCorp, College Station, TX, USA)[23]. According to previously published data, we assumed an overall accuracy of MRI in the diagnosis of placenta accreta equal to 68%, and an estimated κ of 0.58[6–9]. Based on these data, and considering the presence of four raters, we estimated that 13 participants would provide a two-sided 95% CI for κ with a width of ± 0.08.

RESULTS

Forty-six women were included in the study, and the general characteristics of the study population are presented in Table 1. Median maternal age was 34.0 (IQR, 30.3–37.0) years, median parity was 1 (IQR, 1–2) and median number of prior CDs was 1 (IQR, 1–2). The median gestational age at MRI was 33.8 (IQR, 33.1–34.0) weeks. A final diagnosis of placenta accreta, increta and percreta was made in 15.2%, 17.4% and 50.0% patients, respectively.

The IRAs and κ values for agreement between examiners when assessing the different MRI parameters are reported in Table 2. There was excellent agreement between the four examiners in the assessment of the overall presence of a PAS disorder (IRA, 92.1% (95% CI, 86.8–94.0%); κ, 0.90 (95% CI, 0.89–1.00)). Despite this, there was significant heterogeneity in IRA when assessing the different MRI signs suggestive of a PAS disorder. Agreement between the examiners was almost perfect for the presence of placental lacunae (κ, 0.95 (95% CI, 0.89–1.00)), while it was substantial when assessing the characteristics of the lower uterus–bladder interface (κ, 0.64 (95% CI, 0.55–0.74)) and the presence of heterogeneous signal intensity within the placenta (κ, 0.70 (95% CI, 0.63–0.71)).

The depth of placental invasion was based on histopathological examination of the removed uterus and was classified into placenta accreta, increta or percreta. There was almost perfect agreement between the examiners in the identification of the depth of placental invasion on MRI (IRA, 98.9% (95% CI, 96.8–100.0%); κ, 0.95 (95% CI, 0.89–1.00)). However, when assessing the topography of placental invasion, there was only moderate agreement between the four examiners (IRA, 72.8% (95% CI, 72.7–72.9%); κ, 0.56 (95% CI, 0.54–0.66)) (Table 2).

Table 1 General characteristics of 46 women with low-lying placenta or placenta previa who underwent magnetic resonance imaging (MRI) for assessment of presence, depth and topography of placenta accreta spectrum (PAS) disorders

Characteristic	*Value*
Maternal age (years)	34.0 (30.3–37.0)
Parity	1 (1–2)
Number of prior Cesarean deliveries	1 (1–2)
Gestational age at MRI (weeks)	33.8 (33.1–34.0)
Position of placenta	
Anterior	46 (100.0)
Posterior	0 (0.0)
Lateral	0 (0.0)
Final diagnosis	
No PAS disorder	8 (17.4)
Placenta accreta	7 (15.2)
Placenta increta	8 (17.4)
Placenta percreta	23 (50.0)
Vascular invasion of parametria	12 (26.1)

Data are given as median (interquartile range) or *n* (%).

More importantly, when considering parametrial invasion, which is one of the most significant prognostic factors of surgical outcome, the agreement between examiners was substantial and moderate in judging the presence of invasion in the coronal plane (IRA, 86.6% (95% CI, 86.5–86.7%); κ, 0.69 (95% CI, 0.59–0.71)) and axial plane (IRA, 78.6% (95% CI, 78.5–78.7%); κ, 0.56 (95% CI, 0.33–0.60)), respectively. Likewise, interobserver agreement in judging the presence and number of newly formed vessels in the parametrial tissue was moderate (IRA, 88.0% (95% CI, 88.0–88.1%); κ, 0.59 (95% CI, 0.45–0.68)) and fair (IRA, 66.7% (95% CI, 66.6–66.7%); κ, 0.22 (95% CI, 0.12–0.37)), respectively.

DISCUSSION

The findings of this study demonstrate that, in the hands of experienced examiners, MRI has excellent interobserver agreement in identifying the presence and depth of PAS disorders. IRA is lower for the assessment of the topography of placental invasion, especially for the detection of parametrial invasion and the presence of newly formed vessels within the parametrial tissue, which can significantly affect maternal outcome and the choice of an appropriate surgical approach.

Strengths and limitations

The main strength of this study is that evaluation of the MRI scans was carried out by examiners with expertise in the prenatal diagnosis of PAS disorders. Furthermore, the examiners were blinded to the clinical and histopathological findings. Another strength of the study is that we evaluated interobserver agreement for a multitude of MRI parameters related to PAS disorders.

Table 2 Agreement between four expert examiners in assessment of severity of placenta accreta spectrum disorders on magnetic resonance imaging

Parameter evaluated	*Fleiss kappa (95% CI)*	*Interrater agreement (95% CI) (%)*
Presence of PAS disorder (present/absent/unsure)	0.90 (0.89–1.00)	92.1 (86.8–94.0)
Depth of PAS disorder (placenta accreta/placenta increta/placenta percreta)	0.95 (0.89–1.00)	98.9 (96.8–100)
Topography of placental invasion, in sagittal plane (posterior upper bladder wall and uterine body (S1)/posterior lower bladder wall and lower uterine segment and cervix (S2)/no visible bladder invasion)	0.56 (0.54–0.66)	72.8 (72.7–72.9)
Placental invasion of parametrium, in coronal plane (present/absent/doubtful)	0.69 (0.59–0.71)	86.6 (86.5–86.7)
Placental invasion of parametrium, in axial plane (present/absent/doubtful)	0.56 (0.33–0.60)	78.6 (78.5–78.7)
Newly formed vessels in parametrial tissue, in axial plane (present/absent)	0.59 (0.45–0.68)	88.0 (88.0–88.1)
If present, number of newly formed vessels in parametrial tissue (few/multiple)	0.22 (0.12–0.37)	66.7 (66.6–66.7)
Location of placenta (anterior/posterior/lateral/fundal)	1 (–)	100 (100–100)
Coverage of internal uterine orifice by placenta (placenta previa/low-lying placenta)	0.95 (0.89–1.00)	98.9 (96.8–100)
Imaging appearance of placenta (homogeneous/heterogeneous)	0.70 (0.63–0.71)	86.2 (79.4–93.1)
Intraplacental dark bands (not visible/thick/thin/located in lower uterus/confluent)	0.59 (0.48–0.65)	74.6 (65.5–83.8)
Presence of hemorrhagic placental infarction areas (yes/no)	0.52 (0.38–0.69)	86.6 (86.5–86.7)
Presence of placental lacunae (yes/no)	0.95 (0.89–1.00)	98.9 (96.8–100)
If present, number of placental lacunae ($< 4/ \geq 4$)	0.80 (0.70–0.86)	90.6 (90.5–90.6)
If present, shape of placental lacunae (regular/irregular)	0.80 (0.70–0.86)	90.6 (90.5–90.6)
Characteristics of uterus–bladder interface (visible myometrium/ interrupted interface/myometrium not infiltrated and visible near cervix)	0.64 (0.55–0.74)	86.6 (86.5–86.6)
Vascularization of uterus–bladder interface (present/absent)	0.48 (0.25–0.79)	75.7 (75.6–75.7)
If present, characteristics of uterus–bladder interface vascularization (few loci/multiple loci/chaotic)	0.64 (0.53–0.69)	83.3 (83.2–83.4)
Outward bulging of placenta (present/absent)	0.62 (0.53–0.79)	81.9 (81.8–82.1)
Filled bladder (yes/no)	0.76 (0.68–0.95)	93.5 (93.4–93.5)
Presence of artifacts (yes/no)	0.35 (0.13–0.48)	90.2 (90.1–90.3)

The relatively small number of included cases and the high incidence of severe cases of PAS disorder represent the major weaknesses of the study. Another potential limitation is the lack of assessment by less experienced radiologists, as reported in previously published studies. However, cases at high risk for PAS disorders should be referred to centers with expertise in diagnosis and management[25]. Finally, we did not use gadolinium contrast medium for any of the women, thus we could not explore whether its administration would have led to an improved agreement between the examiners.

Interpretation of study findings and implications for clinical practice

The depth and topography of placental invasion are the main determinants of surgical outcome in women affected by PAS disorders[12,13]. The depth of invasion is commonly ascertained on histopathological assessment of the uterine specimen after hysterectomy. However, such assessment is retrospective and therefore not useful when planning surgery. Furthermore, different degrees of placental invasion may coexist in the same uterus.

The identification of the area invaded by the placenta may provide useful information when planning surgery in women affected by PAS disorders. Placental invasion into the lower uterine segment and posterior lower bladder may result in severe maternal complications, even in early pregnancy. Surgical dissection in cases with placental invasion into the lower bladder can cause serious maternal morbidity, especially because of the narrow space, wide connection with anastomotic pedicles and the presence of fibrous tissue between the invaded area and the bladder, which render achieving adequate hemostasis very challenging. Conversely, placental invasion into the upper posterior bladder is easier to manage, mainly because bleeding is more controllable and surgical access is easier. Parametrial invasion is associated with placental adherence to the retroperitoneal structures, including the iliac and ovarian vessels, bladder and ureter[12]. Furthermore, the presence of newly formed vessels in the parametrial tissue may represent an additional risk factor for massive hemorrhage during surgery and may also lead to ureteral invasion.

Despite its importance in predicting the outcome of a PAS disorder, assessment of the topography of placental invasion has not been consistently reported in the published literature. Accurate knowledge of the topography of placental invasion is fundamental for prenatal counseling with respect to the potential surgical risks or the feasibility of conservative resective techniques such as the Triple-P procedure or one-step conservative surgery[26,27]. Although the choice of optimal surgical approach is made after visualization of the actual degree of placental invasion at the opening of the peritoneum, appropriate knowledge of the topography of invasion would enable the surgeon to consider the different management options before surgery.

No study has evaluated the diagnostic accuracy of ultrasound in describing the topography of placental invasion in women with PAS disorders. One of the most objective attempts to categorize the topography of invasion has

been recently provided by Palacios-Jaraquemada *et al.*[12] using MRI. The importance of such a classification system lies in its ability to predict surgical outcome, with women presenting with S2 invasion being at higher risk for severe complications in view of the higher risk of parametrial invasion and the more challenging surgical setting.

In this study, there was moderate agreement between the four examiners in the description of the topography of placental invasion. Likewise, there was also moderate agreement in assessing the presence of parametrial invasion and newly formed vessels in the parametrial tissue. These findings highlight the need for future multicenter collaboration between clinical and research groups in order to develop an objective prognostic prenatal MRI staging system for PAS disorders.

Conclusions

MRI has excellent interobserver agreement in identifying the presence and depth of placental invasion; however, the IRA in ascertaining the topography of the invasion is moderate. This highlights the need for objective standardization of the MRI assessment of PAS disorders and the creation of a reproducible MRI prenatal staging system aimed at stratifying the surgical risks of women affected by these conditions.

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SUPPORTING INFORMATION ON THE INTERNET

The following supporting information may be found in the online version of this article:

Appendix S1 List of MRI characteristics assessed by four examiners