Abdominal Radiology (2019) 44:2572–2581
https://doi.org/10.1007/s00261-019-02008-0

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Placenta accreta spectrum: value of placental bulge as a sign of myometrial invasion on MR imaging

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Published online: 9 April 2019

Abstract

Purpose To evaluate correlation of "placental bulge sign" with myometrial invasion in placenta accreta spectrum (PAS) disorders. Placental bulge is defined as deviation of external uterine contour from expected plane caused by abnormal outward bulge of placental tissue.

Materials and methods In this IRB-approved, retrospective study, all patients undergoing MRI for PAS disorders between March 2014 and 2018 were included. Patients who delivered elsewhere were excluded. Imaging was reviewed by 2 independent readers. Surgical pathology from Cesarean hysterectomy or pathology of the delivered placenta was used as reference standard. Fisher's exact and kappa tests were used for statistical analysis.

Results Sixty-one patients underwent MRI for PAS disorders. Two excluded patients delivered elsewhere. Placental bulge was present in 32 of 34 cases with myometrial invasion [True positive 32/34 = 94% (95% CI 0.80–0.99)]. Placental bulge was absent in 24 of 25 cases of normal placenta or placenta accreta without myometrial invasion [True negative = 24/25, 96% (95% CI 80–99.8%)]. Positive and negative predictive values were 97% and 96%, respectively. Placental bulge in conjunction with other findings of PAS disorder was 100% indicative of myometrial invasion ($p < 0.01$). Kappa value of 0.87 signified excellent inter-reader concordance. In 1 false positive, placenta itself was normal but the bulge was present. Surgical pathology revealed markedly thinned, fibrotic myometrium without accreta. One false-negative case was imaged at 16 weeks and may have been imaged too early.

Conclusions Placental bulge in conjunction with other findings of invasive placenta is 100% predictive of myometrial invasion. Using the bulge alone without other signs can lead to false-positive results.

Keywords Placenta accreta spectrum · PAS disorder · Placental bulge · Uterine bulge · MR imaging · Placenta increta · Myometrial invasion

Introduction

Placenta accreta spectrum (PAS) includes disorders of abnormal placental adherence and invasion where the placenta is directly implanted on the myometrium without intervening decidua [1]. Depending on the degree of invasion, it has been further classified as placenta accreta (placenta adherent to the decidua and myometrium), placenta increta (placenta invading the myometrium), and placenta percreta (placenta invading through and beyond the uterine serosa) [1, 2]. The most likely initial inciting event is believed to be a defect in the endometrial–myometrial interface [2], leading to inadequate decidualization at the implantation site [1]. This happens most commonly secondary to prior Cesarean section delivery but also due to uterine instrumentation,

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placenta previa (implantation over cervix), and Asherman's syndrome, among other etiologies for decidual paucity [1, 2]. The estimated incidence of PAS disorders is about 1 in 300 pregnancies and has increased 10-fold in the last decade, largely secondary to increased incidence of Cesarean section deliveries [1, 3–5]. The incidence is projected to be 9000 cases per year by the year 2020 [6]. It is a major cause of maternal morbidity from severe maternal hemorrhage, disseminated intravascular coagulation and other coagulopathies, infection, urologic injury, and can even result in maternal death [6, 7]. In a study performed in United States, studying current trends, the Cesarean delivery rate is expected to be 56.2% with resulting 4504 cases of PAS disorders and 130 annual maternal deaths by 2020 [3]. The risk of PAS disorders also increases with multiple C-sections, with the disorder being 2.13 times more likely in women who underwent repeat C-sections [8]. Massive obstetric hemorrhage remains a one of the most severe and potentially avoidable cause of maternal death [1]. Hence, accurate imaging diagnosis prenatally and preoperatively is pivotal. In addition to the diagnosis of this disorder, evaluating for the depth of invasion is extremely important in management of these high-risk cases [7, 9]. The deeper the invasion, the higher the likelihood of associated complications, including increased requirement for blood products, urologic injury, and prolonged intensive care unit admission [2, 7, 10–12].

Imaging during pregnancy is performed primarily with ultrasound [13, 14]. An anatomy scan is performed at 18–20 weeks, which includes a complete evaluation of the placenta [2, 15, 16]. MR imaging has an important complementary role to ultrasound in the evaluation of placental invasion [17–21]. MR imaging features of PAS disorders include presence of heterogeneous placenta, loss of retroplacental clear space, T2 dark bands, prominent intraplacental vascularity, myometrial invasion, cervical invasion, and invasion of adjacent organs [17–22]. Cervical invasion can be suggested by the protrusion of the placenta within the cervical canal, and adjacent organs invasion is evidenced by extrauterine placental mass as well as extensive hypervascularity at vesico-uterine interface [23]. While MR imaging has similar sensitivity and specificity to ultrasound, it has been shown to have a high predictive accuracy in assessing both the depth and topography of placental invasion [18]. It has also been beneficial in cases with posterior placenta previa and in any case with clinical suspicion for accreta and discordant US findings, and in cases in which percreta is suspected [17]. MR imaging is also helpful for surgical planning. Knowing the location of the placenta and its relationship to cervix, bladder, and pelvic sidewall allows for preoperative planning for stents, embolization, and extent of dissection anticipated.

Placental bulge has also been identified as a finding of invasive placenta [2, 17, 18, 24]. By definition, placental bulge is deviation of external uterine contour from expected plane caused by abnormal outward bulge of placental tissue [2, 17, 18, 24]. To date, no specific imaging feature has been identified, which allows the confident diagnosis of myometrial in PAS disorders. Delineation of presence versus absence of myometrial invasion is an important observation as it may lead to increased complications at the time of delivery [7, 10–12]. It may also allow for activation of a multidisciplinary team to discuss perioperative considerations. Most importantly clinical management algorithm can vary from planned Cesarean hysterectomy for cases with myometrial invasion (placenta increta or percreta) to more conservative surgery with attempted delivery of placenta and uterine preservation for some cases of suspected lesser invasion such as accreta [7, 25]. Diagnosing placenta percreta is possible with the presence of placental tissue invading through the serosa and into adjacent organs. However, findings differentiating placenta accreta without myometrial invasion from cases with myometrial invasion remain to be established. In this study, we evaluated placental bulge sign and correlated it with the pathologic presence or absence of myometrial invasion.

Materials and methods

Patient selection

In this IRB-approved, HIPPA compliant study, pregnant women undergoing MR imaging for suspected placenta accreta spectrum consecutively between over 4 years of duration (March 2014–March 2018) were included. Patient list was created by searching PACS for the exam type—MR placenta without contrast. The patients were referred based on clinical suspicion of placenta accreta spectrum, sonographic findings suspicious of placenta accreta spectrum or both. Ultrasound was performed prior to MR imaging for all the cases, but not reviewed for the purposes of this study. Incomplete studies or studies severely degraded by motion artifact were excluded from evaluation. Patients who delivered elsewhere were excluded from the cohort.

MR imaging

MR imaging was performed at 3T MR scanner (General Electronics, Milwaukee, WI). Briefly, the sequences performed were multiplanar single-shot fast spin echo (SSFSE), Axial liver imaging with volume acceleration-flexible (LAVA FLEX) or Multipoint Dixon Dual Echo, high-resolution multiplanar SSFSE focused on the placenta–myometrial interface, axial and sagittal diffusion-weighted images (DWI). Technical details of these sequences are mentioned in Table 1.

Table 1 MRI protocol at 3T for suspected placenta accreta spectrum (PAS) disorder

	NOTES	TR	TE	Flip	Nex	Slice	Matrix	FOV	Phase	oversample	IPAT
Patient should drink water prior to commencing study											
Coronal, Axial and Sagittal Single-Shot Fast Spin Echo (ssFSE)	Uterus to below cervix	2000	100	X	X	4/0	384 × 256	36	R>L	PE FOV 1.0	
Axial LAVA FLEX or mDIXON DUAL ECHO	Center over the placenta	4.2	1.2	15	1	3/0	260 × 256	34	A>P	PE FOV 1.1	
Coronal ssFSE (non-propeller)	High-resolution imaging (reduced field of view), center over the placenta	2000	100	X	X	4/0	384 × 256	26–28	R>L	PE FOV 1.0	
Axial T2 FSE (non-propeller)	No fat saturation, high-resolution imaging (reduced field of view), center over the placenta	4000	120	120	2	4/0	320 × 256	24	R>L	NPW	
Sagittal T2 FSE propeller	No fat saturation, high-resolution imaging (reduced field of view), center over the placenta	11,000	74		2	4/0	256 × 256	24			
Axial and Sagittal Diffusion-Weighted Imaging (DWI)	Multiple *b* values of 0, 50, 500, 1000: ADC maps Routine field of view	5000	30.5		2	6/0	80 × 80	34		PE FOV 1	

Imaging analysis

Imaging was independently reviewed by 2 experienced abdominal radiologists with expertise in placental imaging with 5 years and 15 years of experience. The reviewers were blinded to clinical risk factors, ultrasound findings as well as final pathology results. Any disagreement in reads was resolved by consensus. First, an overall suspicion of PAS disorder was assessed and the presence of a bulge was recorded. Placental location and presence of placenta previa were recorded. Imaging signs of invasive placental were recorded including placental heterogeneity, T2-dark bands, myometrial thinning, abnormal placental and subplacental vascularity, and placental bulge(Table 2). Placental heterogeneity constitutes the presence of heterogeneous signal in the placenta on both T2- and T1-weighted images. T2-dark bands are linear areas of hypointensity, which are often in contact with the maternal surface of the placenta. Abnormal flow voids within the placenta and at the utero-placental interface can be present. Placental bulge sign is defined as deviation of external uterine contour from expected plane caused by abnormal outward bulge of placental tissue [2, 17, 18, 24] (Figs. 2, 3, 4, 5). The worst degree of involvement on MRI was reported ranging from normal, accreta only, presence or absence of myometrial invasion (assessed by the presence of the above described placental bulge sign or frankly visible myoinvasive placenta) to the presence or absence of extrauterine organ invasion (percreta).

Reference standard

Surgical pathology was used as the reference standard. 40 patients underwent Cesarean hysterectomy and 3 patients with previable pregnancies underwent gravid hysterectomy. In these patients, the worst area of placenta accreta spectrum was reported ranging from normal, placenta accreta, myometrial invasion present or absent, extra serosal extension to organ invasion. All except one patient with placenta accreta underwent Cesarean hysterectomies. One patient with accreta underwent low-transverse C-section as a fertility-preserving measure, where the adhered parts of the placenta was left in situ and patient subsequently received uterine artery embolization for hemorrhagic control. Of the patients without any suspicion of PAS disorder on imaging, 15 patients had Cesarean delivery and one had vaginal delivery. In these patients, placenta was removed in its entirety without missing fragments clinically. At surgical and histopathology, the placenta specimen was evaluated for evidence of PAS disorders. Additionally, on postpartum follow-up, none of these patients had suspicion for retained products of conception or received imaging studies for the same (Table 3).

Table 2 MR imaging findings for PAS disorders

MRI finding	Definition
Heterogenous placenta	Heterogeneous signal within the placenta
T2-dark bands	Linear areas of hypointensity on T2-weighted images
Placental bulge	Deviation of external uterine contour from expected plane caused by abnormal outward bulge of placental tissue
Myometrial thinning	Thinned myometrium to less than 1 mm or even imperceptible in the region of the placenta
Abnormal placental and subplacental vascularity	Large flow voids present in the placenta as well as the subplacental bed. Sometimes, these vessels may be continuous with each other.

Table 3 Surgical outcomes for patients

Patient outcomes	Number of patients
Normal delivery with intact placenta delivered	1
Cesarean delivery with intact placenta delivered	14
Cesarean delivery with accreta and placenta left in situ	1
Cesarean hysterectomy with accreta	7
Cesarean hysterectomy with myometrial invasion × *4 of these patients had extrauterine trophoblasts without extrauterine chorionic villi or organ invasion*	32
Cesarean hysterectomy with normal placenta (false positive)	1
Gravid hysterectomy with myometrial invasion (previable pregnancy)	3

Statistical analysis

Statistical analysis was performed using the Fisher's exact test. In order to compare the effectiveness of utilizing results from imaging alone, utilizing results based on the presence of bulge alone, or combining the two types of information, we categorized patients into four groups: those who were (1) imaging suspicion of PAS disorder absent (−)/placental bulge absent (−), (2) imaging suspicion of PAS disorder present (+)/placental bulge absent (−), (3) imaging suspicion of PAS disorder absent (−)/placental bulge present (+), and (4) imaging suspicion of PAS disorder present (+)/placental bulge present (+). We then tested whether these groups were independent of a pathology diagnosis of myometrial invasion using a Fisher's exact test. Inter-reader concordance was calculated using the kappa analysis.

Results

61 patients underwent MRI consecutively for suspected PAS disorders over 4 years. 2 patients who delivered elsewhere were excluded from the study and a total of 59 patients were included for statistical analysis (Fig. 1). All the patients imaging was sufficient for imaging evaluation. No patients were excluded on the basis of technical factors. Patient age ranged from 25.5 years to 43 years (average age of 34.6 years, median 34.0 years). All our patients had previous uterine instrumentation as an identified risk factor. The

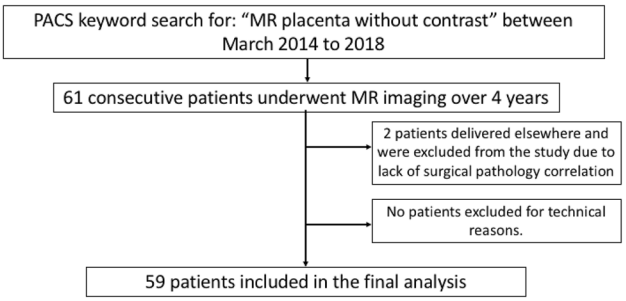

Fig. 1 Flow diagram showing patient inclusion and exclusion criteria

number of C-sections prior to the current pregnancy ranged from 0 to 8 (average 2 and median 2). 3 patients did not have prior C-sections, and had risk factors including abdominal myomectomy, endometrial ablation and dilatation, and curettage for prior abortions, each. Gestational age at MR imaging ranged from 16 weeks 4 days to 37 weeks 6 days, with a mean age of 31 weeks 2 days.

40 patients underwent Cesarean hysterectomy and 3 patients with previable pregnancies underwent gravid hysterectomy. Of the patients without any suspicion of PAS disorder on imaging, 15 patients had Cesarean delivery and one had vaginal delivery. Pathology revealed 17 normal placenta and 8 cases of placenta accreta. 34 cases had myometrial invasion confirmed on pathology. 4 of these 34 cases had microscopic evidence for the presence of extraserosal trophoblasts without extrauterine chorionic villi or frank organ

invasion and hence were not diagnosed as percreta based on our current institutional pathology protocols.

The results of statistical analysis using Fisher's exact tests were as follows (Table 4):

1. Of those who were positive for suspicion for PAS disorder AND bulge present: 32/32 had myometrial invasion = 100% (95% CI 89–100%)
2. Of those who were positive for suspicion for PAS disorder AND bulge absent: 2/10 = 20% (95% CI 3–56%)
3. Of those who were negative for imaging suspicion for PAS AND bulge present: 0/10 had disease = 0% (95% CI 0–31%)
4. Of those who did not have imaging suspicion for PAS AND bulge absent: 0/16 had disease = 0% (95% CI 0–21%).

Placental bulge was present in 32 of 34 cases with myometrial invasion [True positive 32/34 = 94% (95% CI 0.80–0.99)] (Figs. 2, 3, 4, 5). Placental bulge was absent in 24 of the 25 cases of normal placenta or placenta accreta without myometrial invasion [True negative = 24/25, 96% (95% CI 80–99.8%)]. Positive and negative predictive values were 97% and 96%, respectively. Placental bulge in conjunction with other findings of PAS disorder was 100% indicative of myometrial invasion ($p < 0.01$).

Kappa value of 0.87 signified excellent inter-reader concordance. In 1 false positive, placenta itself was normal but the bulge was present (Fig. 6). On surgical pathology, this patient has markedly thinned, fibrotic myometrium without accreta. 1 false-negative case was imaged at 16 weeks and may have been imaged too early.

Discussion

Our results indicate that the presence of placental bulge sign in a patient with MR imaging features of invasive placenta is 100% predictive of myometrial invasion (Figs. 2, 3, 4, 5). Presence of myometrial invasion is an important observation for presurgical planning. These patients have increased risk of postpartum hemorrhage, urologic injury, among other risks, and increase the likelihood of non-conservative management with Cesarean hysterectomy. Anticipating these complications will allow for delivery planning in a center of excellence with multidisciplinary teams well versed in managing these high-risk cases.

Prenatal diagnosis of the depth of myometrial invasion is essential for personalized management of PAS disorders, with options including conservative and fertility-preserving surgery versus Cesarean hysterectomy [7, 9]. The severity of complications associated with PAS disorders increases with the depth of invasion [2]. Studies have shown that the risk of hemorrhage in myoinvasive placenta accreta spectrum (increta and percreta) is significantly reduced when this diagnosis has been established antenatally. This difference is particularly important over and above that for placenta accreta only [10]. Also, this study noted that many cases were upstaged at surgical pathology with greater depths of invasion encountered during surgery and subsequently confirmed at pathology [7, 10]. This may be related to the fact that the specific diagnosis of myometrial invasion has been suboptimal with imaging. Hence, there is a need to identify imaging features which can suggest this diagnosis preoperatively. Maternal risks are most severe with placenta percreta, with these women requiring additional blood products, higher risk of urologic injury, and prolonged ICU admission, when compared to women without myometrial invasion [7, 10–12]. Multiple studies have demonstrated improved patient outcomes when women with PAS disorders are cared for by multidisciplinary teams in centers of excellence compared to standard obstetric care [14, 26–29]. Improved outcomes are particularly notable for the invasive forms of implantation, which have myometrial invasion (increta and percreta) [7, 15]. The outcomes are also improved with pre-planned Cesarean hysterectomy rather than emergent hysterectomy [30]. However, appropriate multidisciplinary management can only be arranged with optimal prenatal diagnosis, which includes accurate assessment of the depth of myometrial invasion and the involvement of adjacent pelvic organs [14].

Despite several signs of PAS been described for US, none of these signs have helped differentiate the presence and absence of myometrial invasion from cases with accreta only [2, 15, 16, 31]. Multiple studies have aimed to quantify ultrasound findings to diagnose PAS but were still unable to assess the depth of invasion [32, 33]. In fact, adherent and invasive placentation usually co-exist in the same bed and may further evolve with advancing gestation [2]. This may be the reason why a single sign or a combination of the above signs has not been shown to be accurate for assessing for the presence of myometrial invasion [2, 31].

Table 4 Statistical analysis with χ^2 test

	Imaging suspicion of PAS with placental bulge present	Imaging suspicion of PAS with placental bulge absent
Myometrial invasion present	32	2
Myometrial invasion absent	1	24

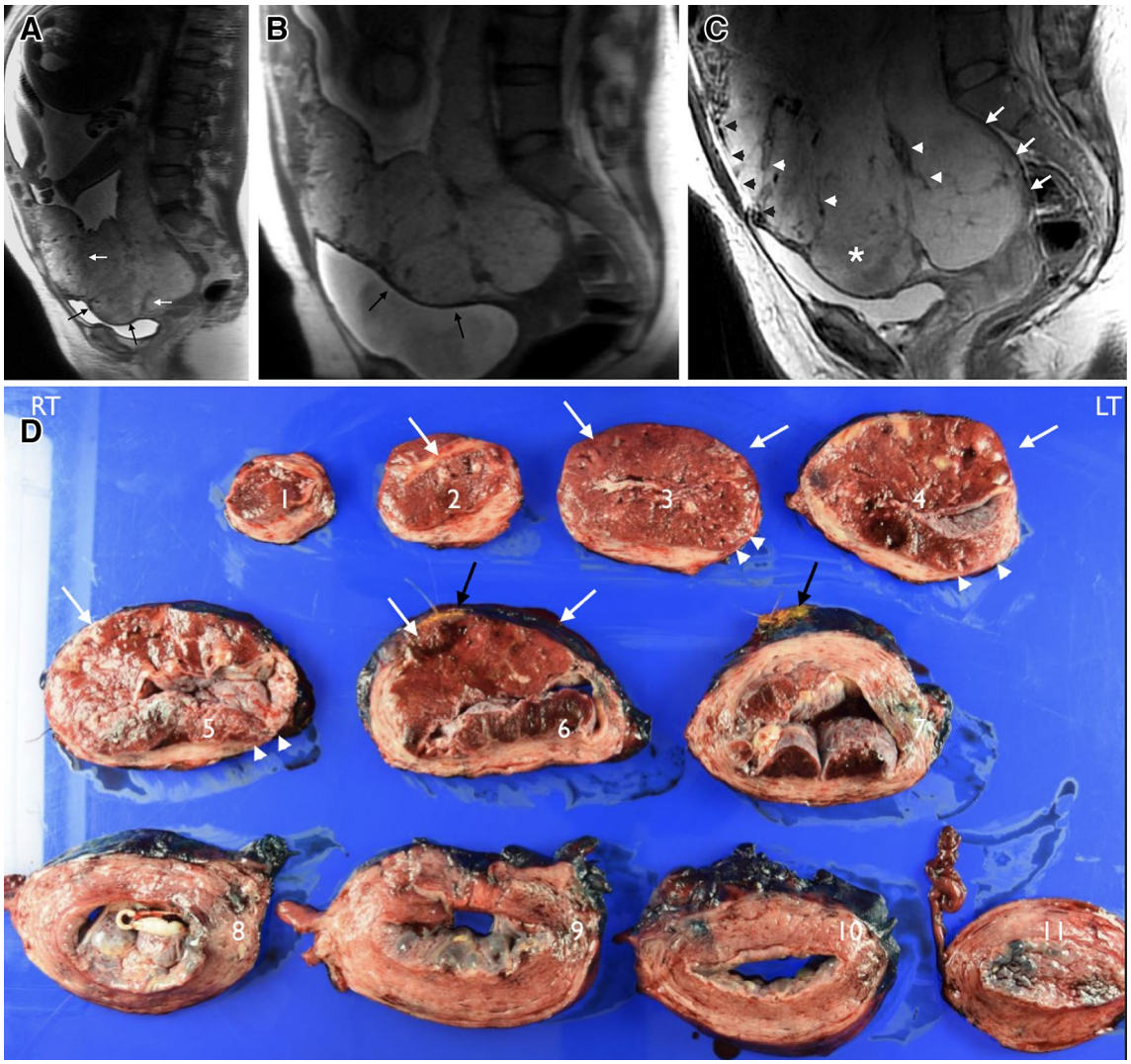

Fig. 2 A 37-year-old woman with history of 2 prior Cesarean sections presents with complete placenta previa and concern for placenta accreta spectrum (PAS) disorder. MRI was obtained at 28 weeks gestational age. **a** Sagittal T2-weighted single-shot fast spin echo (SSFSE) image demonstrates placental bulge as evidenced by uterine bulge and deviation from expected plane (black arrows) most obvious in the anterior and inferior uterus. Bulging into the urinary bladder is noted without clear interruption of bladder wall. T2-dark bands (white arrows) are present in an overall very heterogeneous and thickened placenta. **b** This finding can be less obvious and go unrecognized if bladder is overly distended or completely collapsed (black arrows). Decreased prominence of the bulge is demonstrated in this image when compared with (**a**). **c** Smaller focused field of view of T2-weighted image demonstrates a posterior bulge (white arrows) compared to the more superior uterus. In addition, other features including heterogenous placenta (asterisk), thinning of myometrium (black arrowheads), and T2-dark intraplacental bands (white arrowhead) are also present, overall suspicious for PAS disorder with myometrial invasion. **d**. Intraoperatively, the anterior uterine serosa was densely adherent to the urinary bladder. Axial sections of uterus demonstrate near 100% invasion of myometrium in keeping with increta (white arrows), slices 2–6. Posterior myometrial invasion is also present, although not as deep as the anterior uterus (arrowheads). The serosa was reported to have focal areas of disruption which correlated with the surgical notes to iatrogenic injury due to dissection of dense adhesions (black arrow)

Our results are concordant with those expected by Jauniaux et al. who have previously thought the placental bulge to result from chorionic villous invasion deep into or through the myometrium with secondary loss of structural integrity of the surrounding myometrium [2]. In such scenarios, the placenta is expected to bulge outwards towards the surrounding structures, leading to the "snowman" appearance appreciated at laparotomy [34] and the corresponding bulge seen on ultrasound and MR imaging [2, 18, 24] (Figs. 2, 3, 4, 5).The authors also note that a large proportion of our cases represent pathologically proven placenta increta, which may be reflective of our referral bias. Our center is a tertiary care center noted as a center of excellence for managing high-risk obstetric cases. In this capacity, a lot of cases which we

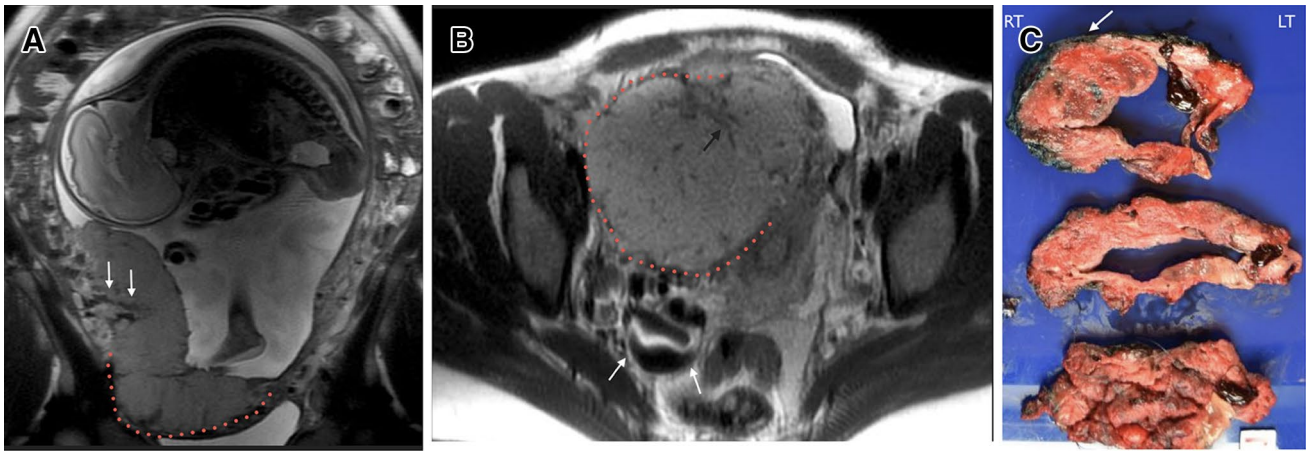

Fig. 3 A 32-year-old woman with 5 prior Cesarean sections presents with concern for placenta accreta on ultrasound (not shown). MRI obtained at 27 weeks gestational age. **a** T2- weighted coronal MR image revealed impressive right placental and uterine bulge, best appreciated on coronal views (dotted outline). The placental tissue appears to bulge outwards to the myometrium as well causing a uterine contour deviation. T2-dark bands are also present (white arrows). **b** Axial T2- weighted MR image demonstrates the placental bulge as evidenced by external contour deviation in the right lower uterine segment, extending from anterior to posterior uterus (dotted outline). Asymmetric parametrial venous congestion is seen on the right (white arrows). Heterogeneous placenta with T2 dark bands (black arrow) was also noted. **c** Axial slices of uterus post-Cesarean hysterectomy demonstrate near 100% invasion of myometrium in right lower uterine segment (white arrow), histology confirmed increta

manage have a higher level of obstetric risk and complexity, hence leading to larger number of cases with myometrial invasion.

Chen et al. have shown that placental bulge and uterine serosal hypervascularity are useful MRI features for differentiating placenta percreta from placenta accreta/increta [24]. However, in their study, they combined both placenta accreta and increta into one group [24]. On the other hand, in our study, we have attempted to differentiate the presence or absence of myometrial invasion, with the help of placental bulge sign. Our results show that the presence of bulge signifies myometrial invasion and will be seen with both increta and percreta. These differences may arise from technique: they used 1.5 T MR imaging [24] compared to 3T imaging in our cohort. The differences may also be related to reference standard used. We used a single reference standard of surgical pathology only. Chen et al. used surgical pathology and intraoperative findings, which may have led to this discrepancy [24].

Limitations of our study include its retrospective nature. Further prospective studies will be helpful to substantiate this finding in practice. Further studies are also required to see if the intraoperative hemorrhagic risk varies with the percentage of myometrial invasion and if that can be predicted based on imaging studies. The authors acknowledge a referral bias as our hospital receives more complex cases and specifically cases for PAS disorders suspected on US. Hence, the currently studied cohort has increased incidence of positive findings.

We noted one false-positive result, where the placental bulge was present. However, the underlying placenta was homogeneous and did not have abnormal imaging findings. This case points to the potential pitfall of using the bulge alone without other imaging features of abnormal placentation. The authors believe that most experts will not call this an invasive placenta based on otherwise normal appearance of the placenta. Pathologic examination of this patient's hysterectomy specimen showed diffuse fibrotic thinning of the myometrium in the region of prior Cesarean section scar, without evidence for abnormal adherence. One false-negative result was also noted in our cohort, where a woman was imaged at 16 weeks for the suspicion of invasive placenta. On MR imaging, the placenta appeared markedly heterogeneous, had prominent lacunes and profound placental vascularity, and was diagnosed as abnormal placental implantation. However, the placental bulge was noted to be absent by both the reviewers. The patient terminated her pregnancy and on surgical pathology, myometrial invasion was present. It is a known fact that imaging early in the pregnancy can lead to false-negative diagnosis of invasive placenta [35]. The authors question if the lack of placental bulge may have been secondary to imaging early in the gestation; however, more research is needed to confirm this. The patient terminated her pregnancy and hence it could not be determined whether a bulge would have appeared later in the pregnancy. We also acknowledge that the cost and availability of MR imaging may be limiting factors for its widespread utilization, and currently it remains an impractical screening tool.

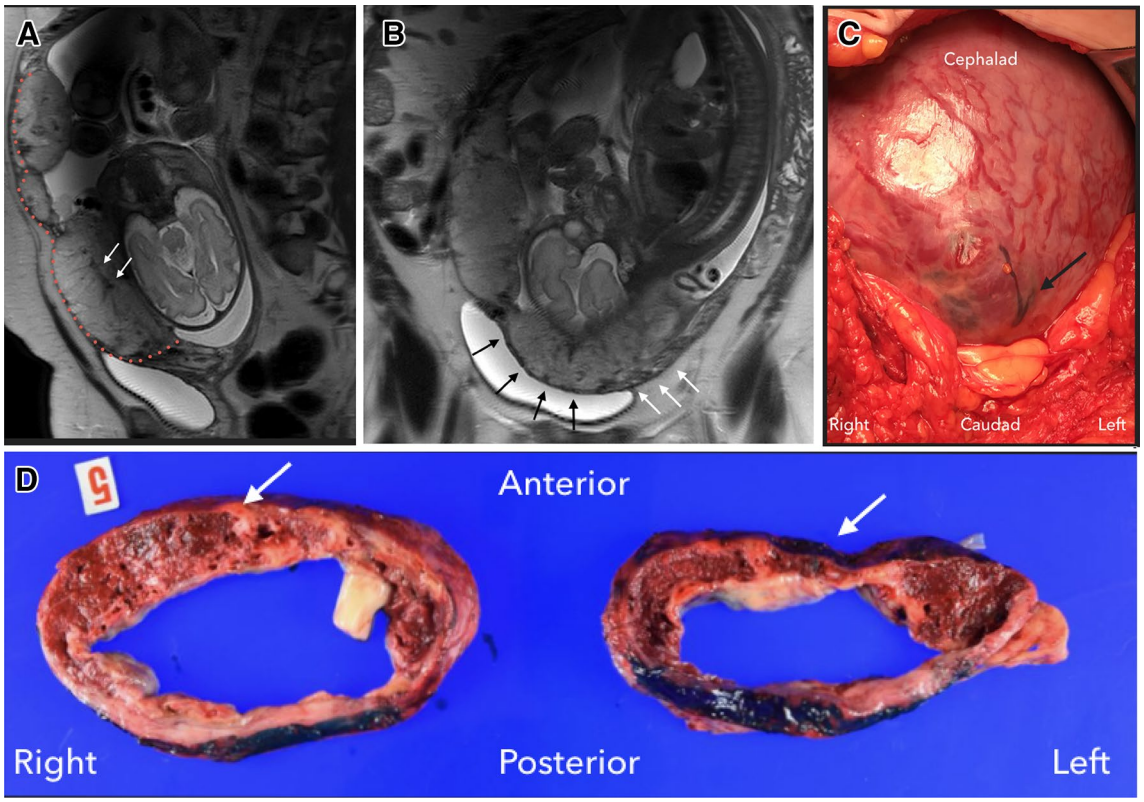

Fig. 4 A 36-year-old woman with history of 1 prior Cesarean section presents with concern for placenta accreta. MRI was obtained at 33 weeks' gestation. **a** Sagittal T2-weighted single-shot fast spin echo (SSFSE) image demonstrates placental bulge and a clear deviation from normal uterine contour anteriorly (dotted outline). T2-dark bands (arrows) are present. **b** Coronal T2-weighted SSFSE image confirms the external contour deviation and asymmetric bulging inferiorly (black arrows). In addition, other features including heterogenous irregular placenta and loss of retroplacental myometrium were also present. Thinning of myometrium is also best appreciated on coronal images, where normal myometrium is seen on the left (white arrows). **c** Intraoperatively visible bulging on the anterior midline surface of the uterus noted suggestive of placenta increta (black arrow). **d** Axial slices of uterus demonstrating near 100% invasion in anterior/lateral aspects of the uterus (white arrows) in keeping with diagnosis of increta

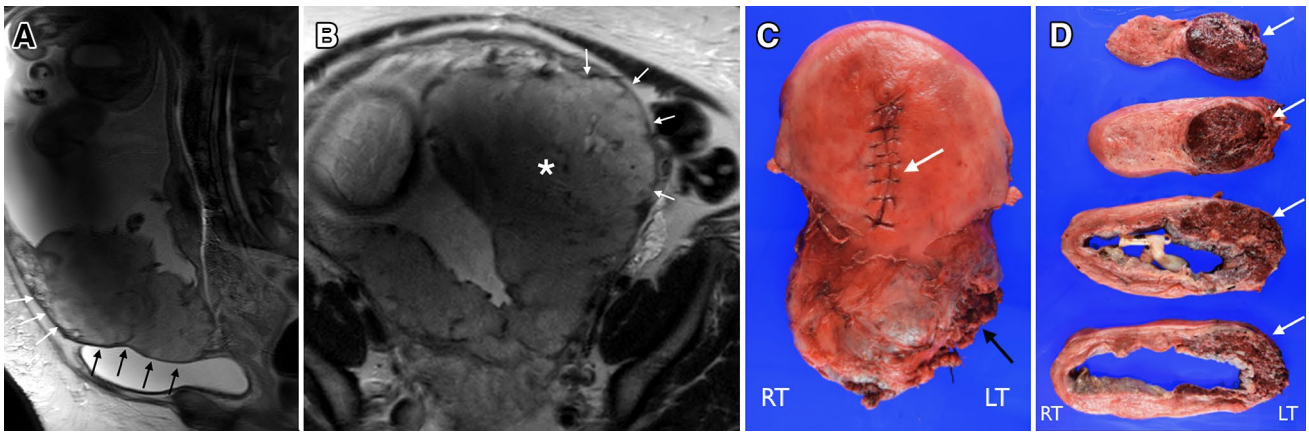

Fig. 5 A 40-year-old woman with history of 2 prior Cesarean sections presents with concern for placenta accreta spectrum (PAS) disorder. MRI obtained at 33 weeks of gestational age. **a** Sagittal T2-weighted single-shot fast spin echo (SSFSE) MR images demonstrate placental and uterine bulge in the anterior inferior uterus (black arrows). Gradual thinning of the myometrium (white arrows) to extensive thinning is noted at the location of the bulge (black arrows). **b** Placental bulge was confirmed on axial T2-weighted SSFSE images (white arrows). In addition, overall heterogenous placenta (asterisk) and prominent vascularity are also present suspicious for myometrial invasion. **c** Gross specimen demonstrates vertical C-section scar (white arrow) with bulging of the lower uterus giving the snowman appearance. Iatrogenic uterine defect in left lower uterine segment (black arrow). **d** Axial slices show near 100% placental invasion of left lower myometrium but still covered by uterine serosa in keeping with diagnosis of placenta increta spectrum (white arrows)

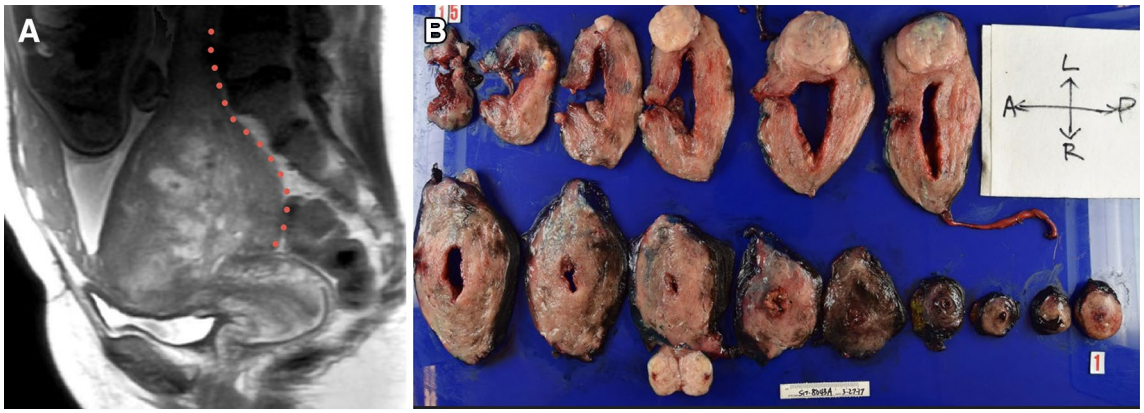

Fig. 6 A 44-year-old woman with history of 2 prior Cesarean section presents with concern for accreta. MRI obtained at 36 weeks. **a** Sagittal T2-weighted image demonstrates posterior contour deviation; however, normal thickness myometrium is noted at this location (dotted contour). Although the placenta appears thickened and heterogeneous, it lacks other features such as prominent T2 dark bands and hypervascularity. On Cesarean hysterectomy, the placenta was not found to be invasive. Retrospectively, there was likely venous myometrial congestion what lead to the appearance of the bulge. **b** Axial slices of hysterectomy specimen. Placenta was removed separately and demonstrated no areas of invasion

In summary, with imaging evidence of abnormal placentation, presence of placental bulge sign definitively points to the presence of myometrial invasion. This is important for appropriate presurgical planning and controlling hemorrhagic risk in this cohort with elevated risk for postpartum hemorrhage. Preparedness for large volume hemorrhage and adjunct measures to control blood loss such as interventional radiology guided embolization or balloon placement can be considered. Ultimately, change in practice with preoperative diagnosis of placenta increta or percreta and its effect on conservative versus non-conservative management options also needs to be further studied.

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