Review Article | Genitourinary Imaging

eISSN 2005-8330
https://doi.org/10.3348/kjr.2020.0580
Korean J Radiol 2021;22(2):198-212

Korean Journal of Radiology

Magnetic Resonance Imaging of Placenta Accreta Spectrum: A Step-by-Step Approach

Sitthipong Srisajjakul, MD[1], Patcharin Prapaisilp, MSc[1], Sirikan Bangchokdee, MD[2]

[1]Division of Diagnostic Radiology, Department of Radiology, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand;
[2]Department of Internal Medicine, Pratumthani Hospital, Pratumthani, Thailand

Placenta accreta spectrum (PAS) is an abnormal placental adherence or invasion of the myometrium or extrauterine structures. As PAS is primarily staged and managed surgically, imaging can only guide and facilitate diagnosis. But, imaging can aid in preparations for surgical complexity in some cases of PAS. Ultrasound remains the imaging modality of choice; however, magnetic resonance imaging (MRI) is required for evaluation of areas difficult to visualize on ultrasound, and the assessment of the extent of placenta accreta. Numerous MRI features of PAS have been described, including dark intraplacental bands, placental bulge, and placental heterogeneity. Failure to diagnose PAS carries a risk of massive hemorrhage and surgical complications. This article describes a comprehensive, step-by-step approach to diagnostic imaging and its potential pitfalls.

Keywords: *Magnetic resonance imaging; MRI of placenta; Placenta accreta spectrum; Step-by-step diagnostic imaging approach*

INTRODUCTION

Placenta accreta spectrum (PAS) comprises of placenta accreta, placenta increta, and placenta percreta, which individually characterize the depth of myometrial invasion from the least severe to most severe types, respectively (1). PAS can be associated with an intractable or massive hemorrhage, requirement of multiple blood transfusion therapies, and increased maternal morbidity and mortality (2). Its major risk factors include placenta previa and a history of prior surgery, especially cesarean section and curettage (1). Diagnostic imaging facilitates the assessment of the extent of myometrial invasion and enhances surgical planning in patients with PAS. Ultrasound (US) has been proven to be a reliable imaging modality for the assessment of PAS in most cases (3). However, in cases where the results of US are equivocal, magnetic resonance imaging (MRI) has emerged as the next-level imaging modality for the diagnosis of PAS (3, 4). The aim of this review article was to describe the role of MRI in the diagnosis of PAS, and provide interpreting radiologists with a comprehensive, step-by-step, diagnostic imaging approach to improve diagnostic accuracy. This guidance will enhance the confidence and ability of attending radiologists to diagnose PAS, which will in turn improve treatment plan and patient outcomes.

Received: May 4, 2020 **Revised:** July 15, 2020
Accepted: July 29, 2020
Corresponding author: Sitthipong Srisajjakul, MD, Division of Diagnostic Radiology, Department of Radiology, Faculty of Medicine Siriraj Hospital, Mahidol University, 2 Wanglang Road, Bangkoknoi, Bangkok 10700, Thailand.
• E-mail: tiam.mahidol@gmail.com
This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (https://creativecommons.org/licenses/by-nc/4.0) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Normal MRI Findings of Gravid Uterus

Normal Placenta on MRI

Normal placenta has a uniform thickness of about 2–4 cm at its middle part. The placenta has both a fetal and a maternal surface. The fetal surface, also known as the chorionic plate, is the place where the umbilical cord inserts or attaches. Showing a smooth external contour, it tapers at a sharp angle toward its edges (5). On MRI, the placenta appears homogeneous and has intermediate signal intensity on T2-weighted image, with clear distinction from the underlying myometrium. In the third trimester, the cotyledon can be identified with intervening fine regular

Copyright © 2021 The Korean Society of Radiology

Korean Journal of Radiology
KJR

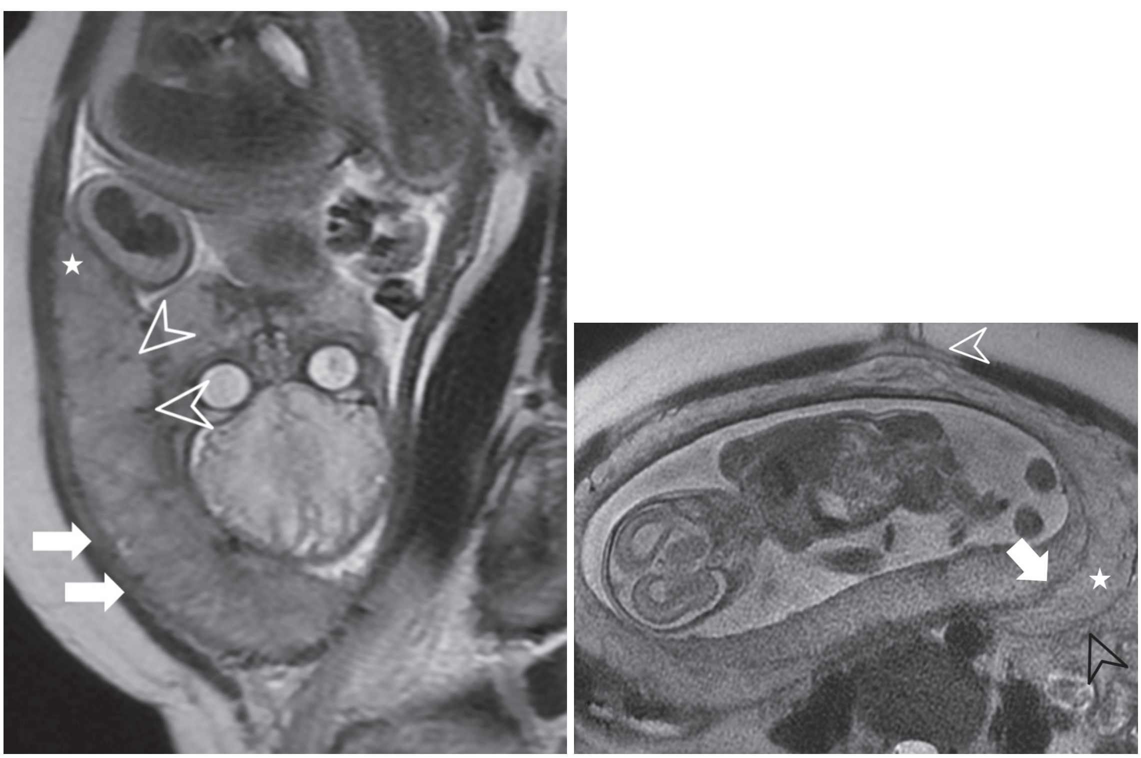
thin septations (1). A few vascular flow voids of less than 5 mm can be seen in the subplacental region and in the placental parenchyma, often near the insertion of the umbilical cord (Fig. 1) (1, 4, 6).

Normal Gravid Myometrium on MRI

The myometrium varies in thickness throughout pregnancy. It shows three layers that are not clearly distinct on T1-weighted image; hence, T2-weighted image is the key imaging sequence (2). In the second trimester, the myometrium has a trilaminar appearance. The inner layer, which comprises decidua basalis and the inner myometrium, forms the uteroplacental interface, while the outer layer represents the uterine serosa. The inner and outer myometrium layers appear with low signal intensity, whereas the thicker middle layer shows high signal intensity, relative to the signal intensity of the placenta, which becomes even higher as the pregnancy progresses (1, 6, 7). A few vascular flow voids are normally seen in the middle layer (Fig. 1). In late pregnancy, usually after 30 weeks, differentiation of the myometrial layers becomes less distinct. The layers become quite thin, and they are visualized as a continuous band or strip of low signal intensity surrounding the placenta on T2-weighted image. Uterine contraction can be observed as a transient localized area of low signal intensity on T2-weighted image. The gravid uterus shows a smooth contour with a wider fundus and body than the lower segment, and it has an inverted pear-shaped appearance (2).

Normal Placenta-Myometrial Interface on MRI

The placenta-myometrial interface is located between the placenta and myometrium, and it blends with the inner layer of the myometrium (5, 8, 9). This area can be seen as a retroplacental dark line or band on T2-weighted image on MRI (Fig. 1), which corresponds with the retroplacental hypoechoic zone on US (5, 8). It is normally seen as a smooth curve of low signal intensity on T2-weighted image on MRI between the placenta and myometrium (10, 11).



A B

Fig. 1. Normal gravid uterus in a 32 year-old-woman at 30 weeks gestation.
A. Sagittal T2 SSFSE shows normal placental thickness, smooth contour, and tapering angular edges (asterisk) with few small vascular flow voids (arrowheads). Interface between decidual basalis and myometrium is intact, depicted as low signal intensity line (arrows), which can become less obvious later in pregnancy. **B.** Axial T2 SSFSE shows normal three layers of myometrium: a low-signal intensity inner layer (arrow), a high-signal intensity thicker middle layer (asterisk), and a thin low-signal intensity outer layer (black arrowhead). This is focal bulge at anterior abdominal wall due to separation of rectus muscles (white arrowhead) as pregnancy progresses, which may be mistaken as an area of invasion. SSFSE = single shot fast spin echo

 https://doi.org/10.3348/kjr.2020.0580

PAS Definition

PAS can be subdivided on the basis of severity of depth of placental tissue extension through the uterine wall: placenta accreta (partial or complete absence of the decidua basalis, with adherence of the placenta to the superficial myometrium); placenta increta (a deeper extension through the myometrium, but not through the uterine serosa); and placenta percreta (penetration through the serosa and possibly into adjacent organs).

A recent article by Einerson et al. (12) proposed that PAS was not due to destructive trophoblastic invasion; the researchers postulated that its pathogenesis resulted from a uterine defect rather than being placental in origin. An abnormally attached placenta does not grow and invade through the myometrium like a malignant tumor. Rather, the trophoblastic villi abnormally implant in a region of defective decidual scar, following which the growth of the placenta causes progressive dehiscence of the myometrium. Tantbirojn et al. (13) proposed that placenta increta and percreta were not caused by invasion of trophoblastic villi into the uterine wall but were more likely secondary to scar dehiscence, providing the route for the chorionic villi to penetrate deep within the myometrium or uterine wall.

The reference standard for treatment of PAS is a cesarean hysterectomy with the placenta retained *in situ* after delivery of the fetus (2, 14). Attempts at placental removal are associated with a significant risk of hemorrhage (14).

Comprehensive, Step-by-Step, Imaging Approach for MRI of PAS

Step 1. Imaging Candidate for MRI

US and MRI are the imaging modalities for antenatal diagnosis of PAS. US is relatively inexpensive, is widely available, and has been reported to have 77–93% overall sensitivity and 71–96% overall specificity (15). Therefore, US remains the first-line imaging modality for diagnosing morbidly adherent placenta. The cardinal findings of PAS on US include placental lacunae, loss of retroplacental clear space, reduction of myometrial thickness, and an irregular bladder wall with increased vascularity (4, 8, 16, 17). However, MRI has been gaining attention as an alternative modality of choice for PAS evaluation and diagnosis especially in cases of posterior and lateral invasion, which are areas that are difficult to assess using US. MRI is also helpful for surgical planning since it accurately demonstrates the location of the placenta relative to adjacent structures (the cervix, bladder, and pelvic side walls) (6, 7). MRI should be therefore performed as an adjunct to US when US findings are inconclusive (1, 2, 6).

Step 2. When to Perform MRI

The accuracy of interpretation of PAS depends on the placental evolution throughout pregnancy. Before the 23rd week of gestation, as the placenta may not be mature, an MRI to evaluate abnormal placentation would not produce satisfactory results (18). However, between the 24th and 30th weeks of gestation, the optimal time to perform an MRI examination to assess PAS, the normal placenta shows a homogeneous intermediate signal intensity and is usually clearly differentiated from the myometrium, which is more hyperintense and heterogeneous (2).

After the 30th week of gestation, the placenta has a more heterogeneous signal intensity on T2-weighted image. This is because the placenta has matured and the uterine wall has thinned, which diminishes the specificity of many of the documented MRI findings of PAS (5). Therefore, the optimal window for performing MRI in this clinical setting is between 24th to 30th weeks of gestation (5). It should be noted that performing MRI later than 30th weeks is not contraindicated because we still can rely on the integration of MRI signs or its correlation with US findings (5, 19-21).

Step 3. Patient Preparation and MRI Protocol

Patients should lie in the supine position inside the magnet bore. However, the left-lateral decubitus position may be more tolerable in near-term pregnancy to reduce the risk of caval compression by the uterus. The bladder should be in a moderately full state for patient comfort and to avoid under- or overdistension, which could affect the bladder invasion assessment. Oxygen via a nasal cannula may be given to patients to reduce fetal movement (1, 21). In patients with claustrophobia, a “feet-first” position may be helpful to keep the head outside the magnet bore.

A multichannel, phased-array, surface coil in a 1.5 tesla (T) system is typically employed. A 3T MRI yields additional benefits (specifically, more frequently identified placental septa and cotyledons) because the 3T MRI provides greater signal intensity and spatial resolution (1). However, the disadvantages of the 3T MRI include susceptibility artifacts, a dielectric effect, and chemical shift artifacts. Interestingly, little is currently known about the harmful effects to the fetus, if any, that may be caused by 3T or a higher field strength MRI (1, 21). At our center, only the 1.5T MRI system is authorized for use in this imaging setting.

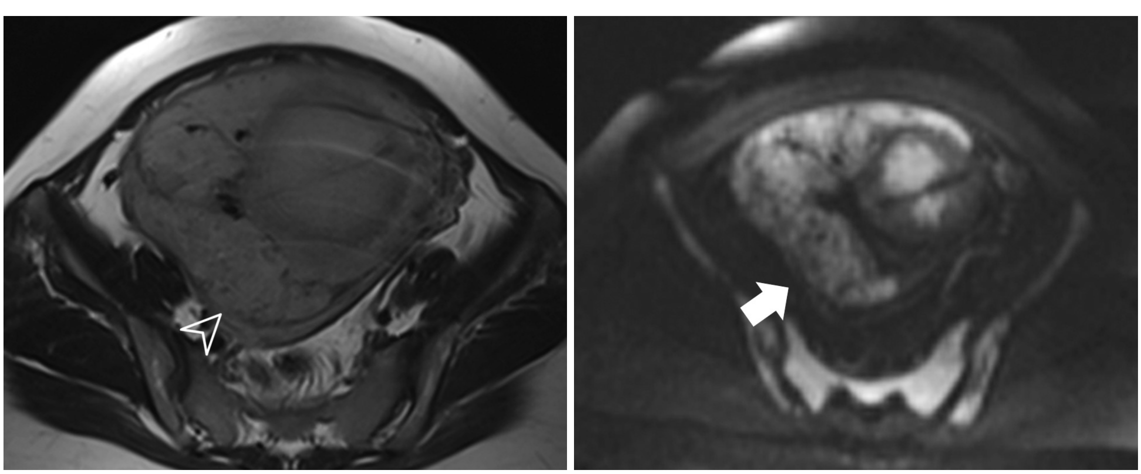
The basic MR sequences that provide rapid imaging are gradient echo and spin echo. Each vendor has its own acronyms for these MR rapid sequences (such as SSFSE, TrueFISP, and FIESTA), which reduce maternal and fetal-motion artifacts (Table 1) (4). Breath-holding should be performed when possible. The sagittal plane is the best plane for visualizing the placenta relative to the uterus (10, 11). If a partial volume averaging artifact occurs, the findings can be confirmed in the other imaging planes or sequences.

Diffusion-weighted imaging (DWI) is a relatively novel technique to evaluate PAS; however, experience with DWI is limited. Reports have suggested that it may be helpful in defining the boundary between the placenta and myometrium (22, 23). At b value of 1000 sec/mm^3, the placenta shows a brighter signal intensity than that of the myometrium. The difference in their intensities enables the clear identification of the interface between the placenta and myometrium, which facilitates improved detection of myometrial invasion (Fig. 2). A potential drawback of DWI is that the myometrium is commonly thin during the third

Table 1. MRI Sequences, Imaging Planes, and Core Benefits for the Diagnosis of PAS

MRI Sequences	Imaging Planes	Core Benefits
T2 SSFSE	Axial: FOV 350–400 mm, 4 mm slice thickness, matrix 320 x 192, TR/TE 1100/90 ms Coronal/sagittal: FOV 350–400, 4 mm section thickness, matrix 320 x 192, TR/TE 1100/90 ms	- Provide anatomic detail and dark intraplacental bands - Placental position - Placental attachment - Depth of placental invasion
Balanced steady-state gradient echo sequence or Fast Imaging Employing Steady-state Acquision	Axial: FOV 350–400 mm, 4 mm slice thickness, matrix 160 x 288, TR/TE 4.2/1.8 ms, NEX = 1 Coronal/sagittal: FOV 320–400 mm, 4 mm slice thickness, matrix 196 x 320, TR/TE 4.6/1.9 ms, NEX = 1	- Anatomical assessment - Assess vascularity - Evaluate adjacent structures
T1-weighted sequence	Axial: FOV 320–400 mm, 4 mm slice thickness, matrix 320 x 192, TR/TE 155/4.2 ms, NEX = 1 Sagittal: FOV 320–400 mm, 4 mm slice thickness, matrix 228 x 224, TR/TE 155/4.2 ms, NEX = 1	- Evaluate subplacental hemorrhage or blood product
Diffusion-weighted image	Axial: FOV 320–400 mm, 5 mm slice thickness b value 50, 750, 1000 sec/mm^2	- Assess myometrial invasion

Side-by-side viewing of SSFSE and balanced steady-state gradient echo sequences paired for axial, sagittal, and coronal planes are the most useful tip on interpretation. FOV = field-of-view, NEX = number of excitations, PAS = placenta accreta spectrum, SSFSE = single-shot fast spin echo, TE = echo time, TR = repetition time



A B

Fig. 2. DWI in a 30 year-old-woman at 30 weeks gestation.
A. Axial T2 SSFSE shows an area of loss of retroplacental T2 dark line at right-posterolateral aspect of uterus (arrowhead) that is questionable for myometrial invasion. **B.** Correlation study with DWI (b value 1000 sec/mm^2) shows normal high-signal intensity of smooth contour placenta (arrow) with no evidence of myometrial invasion. DWI = diffusion-weighted imaging

 https://doi.org/10.3348/kjr.2020.0580

trimester; this thinness may prove to be problematic when attempting to distinguish between the myometrium and placental invasion. Another limitation is that DWI cannot detect placenta accreta as this condition has deficiencies in the decidua layer only without deep placental-tissue invasion into the myometrial layer, and has no focal thinning of the myometrium (10, 23, 24).

The total scan time ranges from 25 to 35 minutes. A radiologist should be present during the examination to guide the technologist if an additional plane perpendicular to the placenta-myometrial interface or the myometrium-bladder interface is needed to better clarify the site of PAS.

Step 4. Identify Risk Factors for PAS and Locate Placenta

The two major risk factors for PAS are prior cesarean section and placenta previa. PAS occurs in 5% of patients with placenta previa, and in up to 10% of patients after four or more cesarean sections. Among women with placenta previa, PAS occurs in 40% of those with two prior cesarean sections, but in 67% of patients who have had four or more cesarean sections (25).

Additional but relatively minor risk factors include uterine anomalies, an advanced maternal age, prior uterine surgery, prior dilatation and curettage, and prior myomectomy. The site of a prior cesarean section scar can be identified on MRI at the anterior aspect of the lower uterine segment (4, 10).

MRI is an excellent imaging modality for identifying placenta previa (6). In normal pregnancy, the lower margin of the placenta is seen at least 2 cm from the margin of the internal cervical os. The 4 types of placenta previa are:

- Low lying placenta (the lower placental margin is within 2 cm of the internal cervical os);
- Marginal previa (the lower placental margin extends to the margin of the internal cervical os);
- Complete previa (the placenta completely covers the internal cervical os); and
- Central previa (the midportion of the placenta—not the margin—completely covers the internal cervical os).

Step 5. Spectrum of MRI Findings of PAS

Various MRI features of PAS with differing sensitivities and specificities are described in the literature (1, 2, 4, 5-9, 11, 26, 27). During image interpretation, none of these MRI features are assessed in isolation, and the more the features that are identified, the greater the concern. Bourgioti et al. (28) correlated specific MR features with clinical outcomes; and found that the presence of ≥ 3 MRI signs correlated with a complicated delivery, while ≥ 6 MRI signs were associated with massive bleeding, a hysterectomy, or extensive bladder repair.

To facilitate understanding and implementation of each MRI feature, the authors grouped all MRI findings by the non-fetal parts of the gravid uterus: the placenta, placenta-myometrial interface, myometrium, and extrauterine structures (Table 2).

Dark Intraplacental Bands

These are observed as a random linear or polygonal bands (6 mm to 20 mm or more) of very low signal intensity on a T2-weighted image, arising from the maternal surface of the placenta (Fig. 3) (1, 10). The bands are thought to be caused by fibrin, perhaps due to repeated hemorrhage and infarction. This finding is one of the most consistent, abnormal MRI features in patients with PAS. The bands tend to be thicker and more irregular than normal placenta septa, which are typically uniformly thin, smooth, and usually regularly spaced (21, 29).

Heterogeneous Placenta

This feature is usually caused by the interplay between hemorrhage, dark intraplacental bands, and deep vascular flow voids. A marked heterogeneity of placenta is a helpful

Table 2. Spectral MRI Findings of PAS

Spectral MRI Findings of PAS (Inside Out Approach)			
			Placenta percreta
Placenta accreta and placenta increta			
IN →			OUT
Placenta	Placenta-myometrial interface	Myometrium	Extrauterine invasion
- Dark intraplacental band - Heterogeneous placenta - Placental bulge - Lumpy contour and rounded edge - Abnormal/disorganized placental vascularity	- Thinning or loss of retroplacental T2 dark zone	- Myometrial thinning - Focal disruption of myometrium	- Bladder or adjacent structural invasion - Focal exophytic mass sign

https://doi.org/10.3348/kjr.2020.0580

Korean Journal of Radiology
KJR

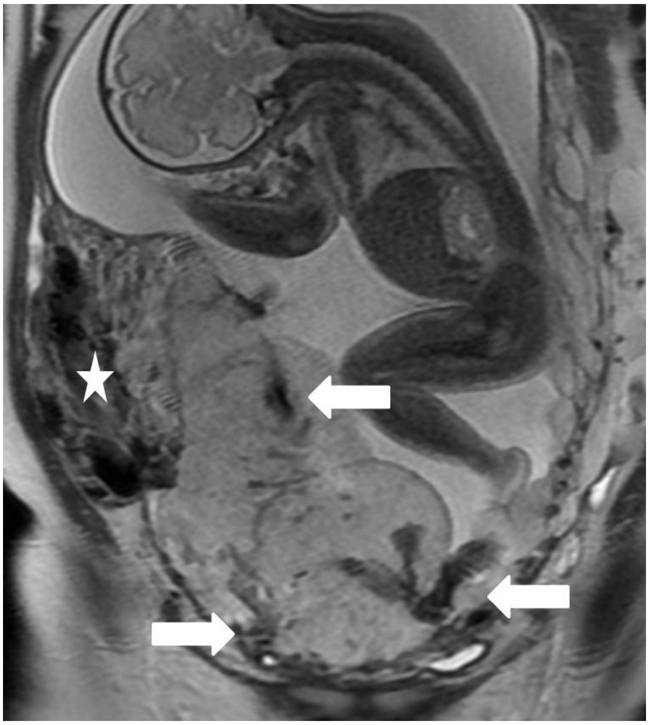


Fig. 3. A 35-year-old woman with PAS. Coronal T2 SSFSE performed at 32 weeks gestation shows moderately heterogeneous signal intensity with abnormal intraplacental dark bands (arrows) and disorganized subplacental hypervascularity (asterisk). Pathological examination revealed placenta percreta. PAS = placenta accreta spectrum

Fig. 4. A 32-year-old woman with placental bulge. Coronal FIESTA performed at 34 weeks of gestation shows right-lateral placental bulge into the myometrium (asterisk). Intact outer layer of myometrium (arrowhead) is depicted. Lumpy contour and rounded edge (arrow) is seen. Pathological examination revealed placenta increta. FIESTA = Fast Imaging Employing Steady-state Acquision

sign of invasive placentation, and PAS is unlikely seen in a homogeneous placenta (Fig. 3) (1, 11). A mild to moderate degree of heterogeneous signal intensity of placental tissue on a T2-weighted image is considered a less useful sign of placental invasion because heterogeneous signal intensity can also be normally seen in the third trimester of pregnancy (the so-called "heterogeneity of aging"), owing to the presence of calcification and vascular lakes (1, 10). This sign is a relatively nonspecific indicator due to the high degree of subjectivity in assessment.

Placental Bulge

This sign refers to an abnormal placenta that has implanted in the lower uterine segment, causing abnormal uterine bulging. It is identified as a deviation of the uterine serosa away from the expected plane (Figs. 4, 5). Leyendecker et al. (30) suggested that a placental bulge is the most useful sign in isolation. There are two forms of placental bulge. The first is a diffuse bulge of the lower uterine segment contour, which results in loss of the typical, inverted-pear shape (this can be observed in normal pregnancies). The other is a smaller, focal bulge into myometrium, which has been reported to be more useful for diagnosing PAS (30). The uterus develops an hourglass or snowman configuration (snowman sign) instead of the typical, inverted-pear shape (1, 11). This feature is best observed in the sagittal or coronal planes, but it can also be seen on the axial plane when the bulging is lateral in location (11). The presence of a placental bulge has been found to be associated with deep depths of myometrial invasion. A placental bulge and uterine serosal hypervascularity are useful MRI features for differentiating placenta percreta and increta from placenta accreta (7, 9-11).

Lumpy Contour and Rounded Edge

Normal placenta has a smooth contour and tapering, angled edges (5). The lumpy contour and rounded edge that result from placental tethering are imaging features that can be identified in PAS (Fig. 6) (5, 11). These findings are frequently observed with a placental bulge.

Abnormal or Disorganized Intraplacental and Subplacental Vascularity

The presence of a disorganized intraplacental vascularity can help to establish a diagnosis of PAS (10, 11). This finding has long been documented in the sonographic literature. It is defined as a dilated tortuous signal void (> 6 mm) or clump of intraplacental vessels on T2 HASTE within the placental parenchyma, which becomes high signal intensity on TrueFISP sequence, consistent with abnormal vascularity. These disorganized vessels are frequently located near the areas of dark intraplacental banding on T2-weighted image, and they may occasionally extend beyond the placenta to the underlying myometrium.

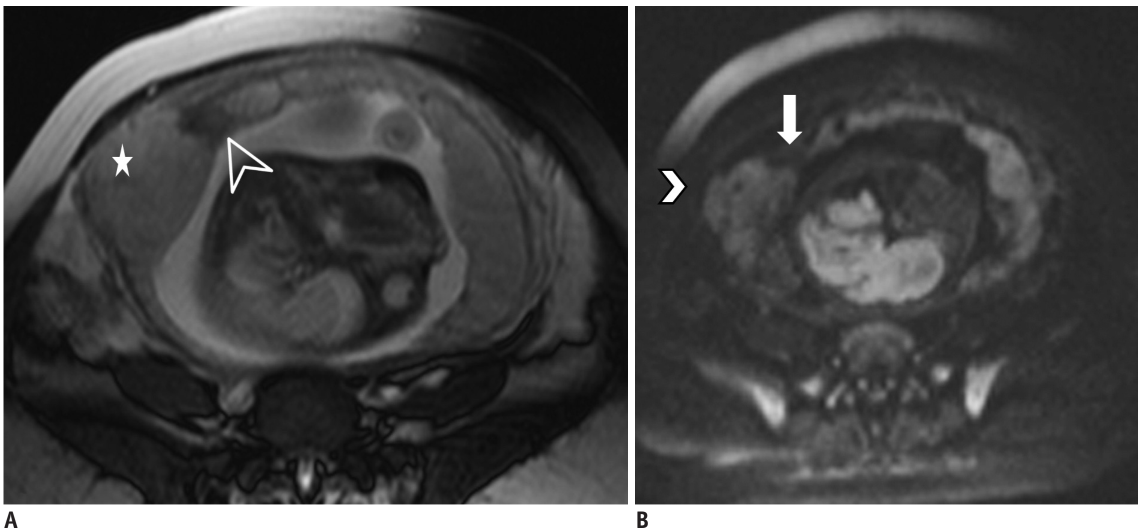


Fig. 5. A 34-year-old woman with PAS at 31 weeks gestation.
A. Axial T2 SSFSE shows lateral placental bulge at right-lateral aspect (asterisk) and adjacent intraplacental dark band (arrowhead). **B.** DWI (b value 1000 sec/mm^2) shows high-signal intensity of placenta with focal myometrial invasion (arrowhead). Dark intraplacental band is low-signal intensity on DWI (arrow). Pathological examination revealed placenta increta.

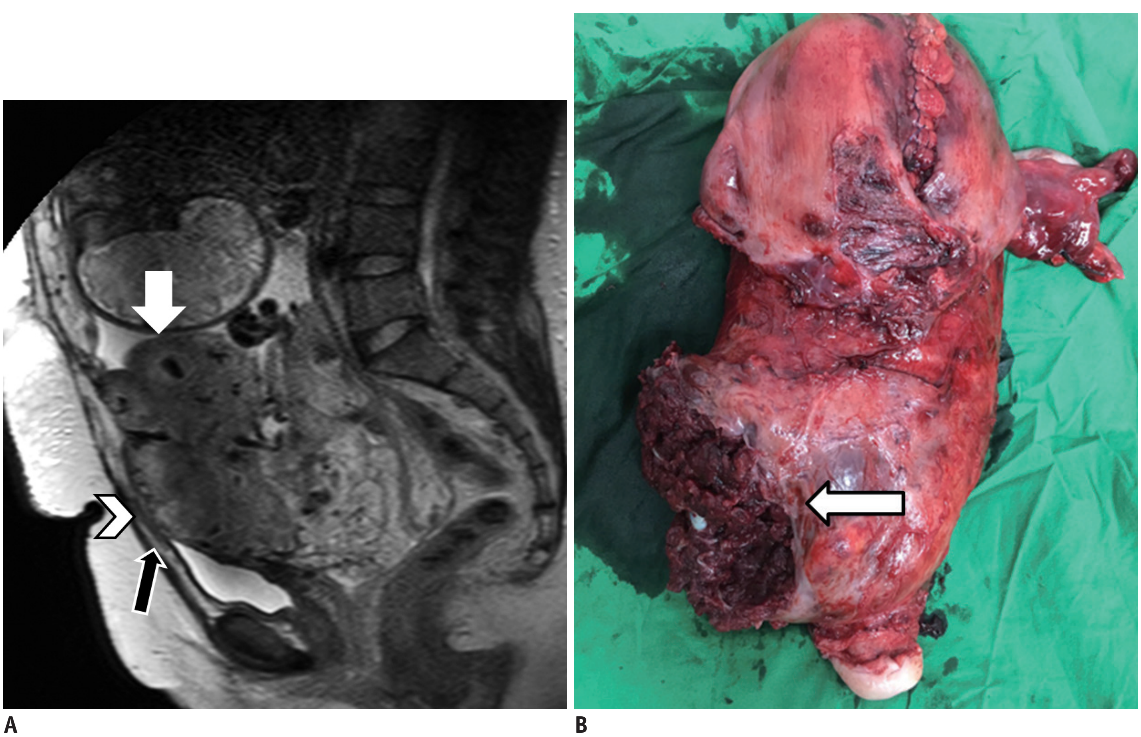


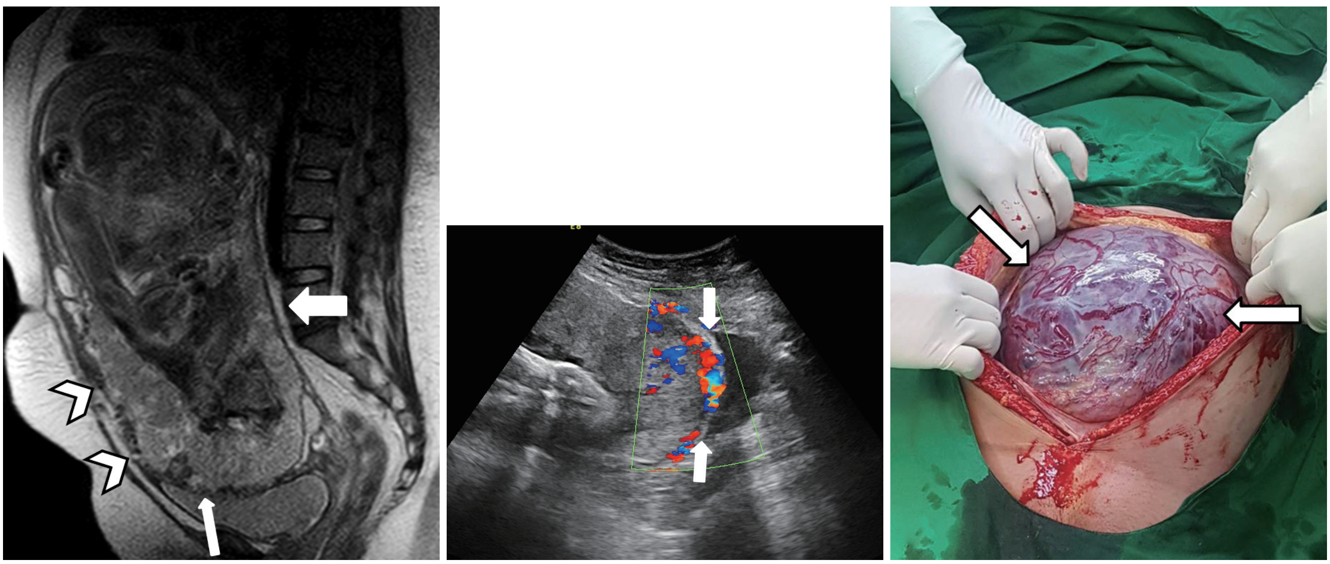
Fig. 6. A 33-year-old woman with PAS at 34 weeks gestation.
A. Sagittal T2 SSFSE shows complete placenta previa with placental bulge, loss of retroplacental dark line, and bulging of lower uterine segment (arrowhead). Heterogeneous signal intensity with rounded edge and lumpy contour due to tethering effect are identified (arrow). Tenting bladder is seen (black arrow). **B.** Four weeks later, cesarean section was performed with hysterectomy. Placenta percreta was confirmed (arrow).

https://doi.org/10.3348/kjr.2020.0580

The resulting subplacental vascularity can cross the uterine serosa and may be associated with extensive neovascularity around the uterus, cervix, vagina, and bladder (Fig. 7) (9, 26, 27). This has led to the recent proposal of a sign termed the "stripped fetal vessel sign," defined as a large caliber intraplacental vessel that extends between the maternal and fetal placental surface without change in vessel caliber (Fig. 8) (31).

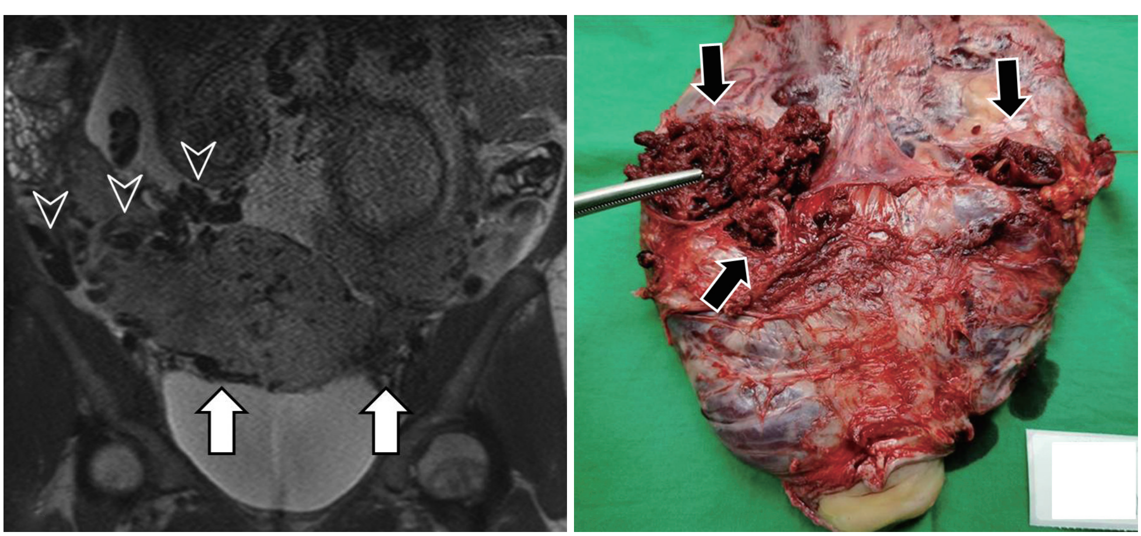
Thinning or Loss of Retroplacental T2 Dark Zone

The placenta-myometrial interface is interrupted in PAS cases since it is detected on MRI as a loss of the retroplacental dark line on a T2-weighted image. This finding is usually associated with other signs, such as a



A B C

Fig. 7. A 39-year-old woman with PAS at 32 weeks gestation.
A. Sagittal T2 SSFSE shows complete placenta previa with loss of low-signal intensity at interface between bladder and uterus (thin arrow). There is marked myometrial thinning, with increased vascularity or neovascularization along anterior lower uterine segment and superior aspect of bladder (arrowheads), which is in contrast to normal appearance of posterior aspect of myometrium (thick arrow). **B.** Color Doppler US shows uterovesical hypervascularity with multidirectional flow and aliasing artifact (arrows). **C.** Intraoperative finding shows an extraordinary volume of tortuous vessels at external or serosal surface of gravid uterus (arrows). Pathological examination revealed placenta percreta. US = ultrasound



A B

Fig. 8. A 39-year-old woman with PAS at 35 weeks gestation.
A. Coronal T2 SSFSE shows irregularity or spiculation and increased vascularity at the interface (arrows) between bladder and uterus. The Stripped fetal vessel sign (arrowheads) is seen, and vessel diameter is greater than 6 mm. **B.** Multiple sites of placenta percreta were found after surgery (arrows).

 https://doi.org/10.3348/kjr.2020.0580

focal myometrial defect and myometrial thinning (10, 11). Placental tissue that extends through the myometrium with interruption of the retroplacental T2 dark zone can be identified in patients with placenta percreta.

Fig. 9. A 38-year-old woman with PAS at 34 weeks gestation.
Coronal FIESTA shows thinning of anterior myometrium with bulging of lower uterine segment and lobulated external contour (arrowheads). No intraplacental dark band is seen. Placental accreta was confirmed at delivery.

Myometrial Thinning

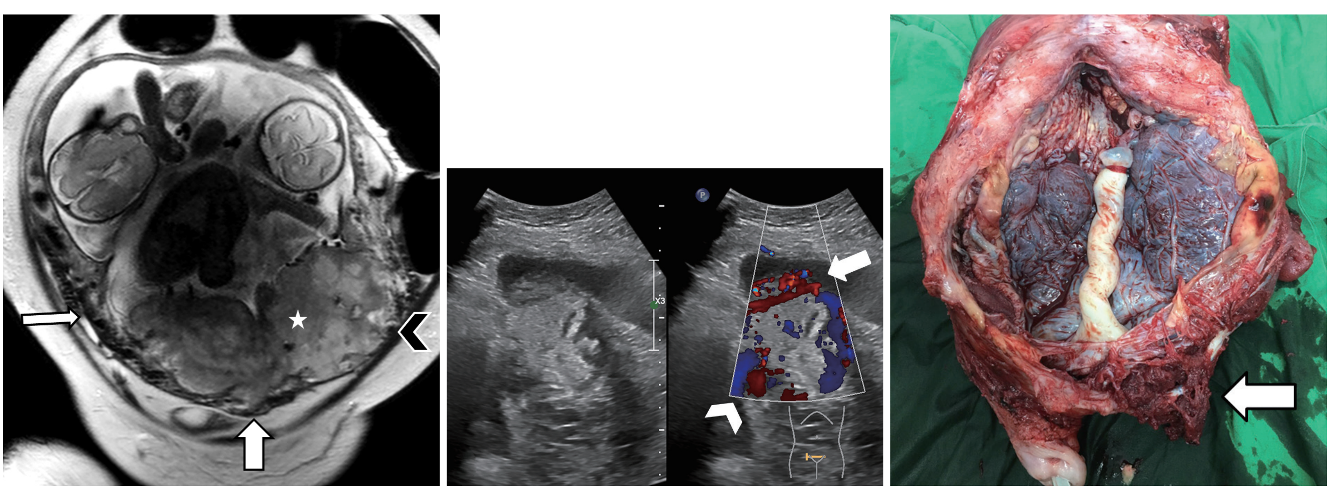
This is the earliest MRI sign to suggest PAS. The myometrium may appear thin (even less than 1 mm) in the area of the placental attachment, and it probably becomes imperceptible in PAS (Fig. 9) (5, 7-9). This sign is reported to have low sensitivity and specificity due to the physiological thinning of the myometrium as pregnancy progresses; therefore, the myometrium is difficult to visualize, especially at the site of a previous surgical or cesarean section scar (5, 7-9, 26, 27). Therefore, when myometrial thinning is detected, additional imaging features should be sought to help diagnose PAS.

Focal Disruption of Myometrium

Focal disruption of the myometrium is identified at the site of placental invasion. This imaging feature can be observed only when the myometrium is well depicted (11). Alamo et al. (32) suggested this sign is the second most common criterion in cases of placental invasion, with a sensitivity of 91% (Fig. 10).

Step 6. Identify MRI Findings of Extrauterine Extension (Placenta Percreta)

It is crucial to identify the depth of invasion and signs that suggest placenta percreta, especially bladder invasion. This is because bladder invasion by the placenta poses a



A B C

Fig. 10. A 35-year-old woman with PAS at 35 weeks gestation twin pregnancy.
A. Coronal T2 SSFSE shows focal interruption of myometrium at midline (thick arrow), and left-lateral placental bulge with marked thinning of myometrium (arrowhead). Heterogeneous signal intensity of placenta (asterisk) and increased flow voids at myometrium (thin arrow) are detected. **B.** US shows multiple tortuous hypoechoic structures within the placenta that were confirmed to be placental lacunae on Doppler US (arrowhead); and placental bulge with increased vascularity at the interface between bladder and uterus (arrow). **C.** Cesarean section and hysterectomy were performed, and placenta percreta was found (arrow).

https://doi.org/10.3348/kjr.2020.0580

high risk for life-threatening obstetric complications if attempts are made to remove the adherent placenta from the bladder. This procedure causes massive or intractable bleeding that is somewhat difficult to control (33).

The criteria for bladder extension include interruption of the bladder wall, tenting of the bladder dome, marked chaotic vascularity at the interface between the uterus and bladder, and focal placental tissue inside the bladder. With no direct visualization of the placental tissue in the lumen of the bladder, it is somewhat difficult to determine the presence of bladder invasion. Although adherence of the placenta to the bladder wall is technically not a true invasion of the bladder wall, separation during delivery can cause serious bleeding and result in a torn bladder wall (34). Therefore, the radiologist should err on the side of caution when the finding of bladder invasion is encountered.

In the case of placental invasion into the adjacent pelvic organs (focal exophytic mass sign), such as the rectum, parametrium, or pelvic side wall or muscles (Fig. 11), MRI is preferred over US. MRI provides a wider field of view, which improves surgical planning (4, 11, 35).

Step 7. Check for Potential Imaging Pitfalls

Placental Vascularity

A few, normal vascular flow voids can be identified in the subplacental region and within the placenta (< 6 mm; Fig. 12A) (1, 10, 11). In the latter area, they are usually seen in the region of the insertion point of the umbilical cord.

Dark Intraplacental Bands

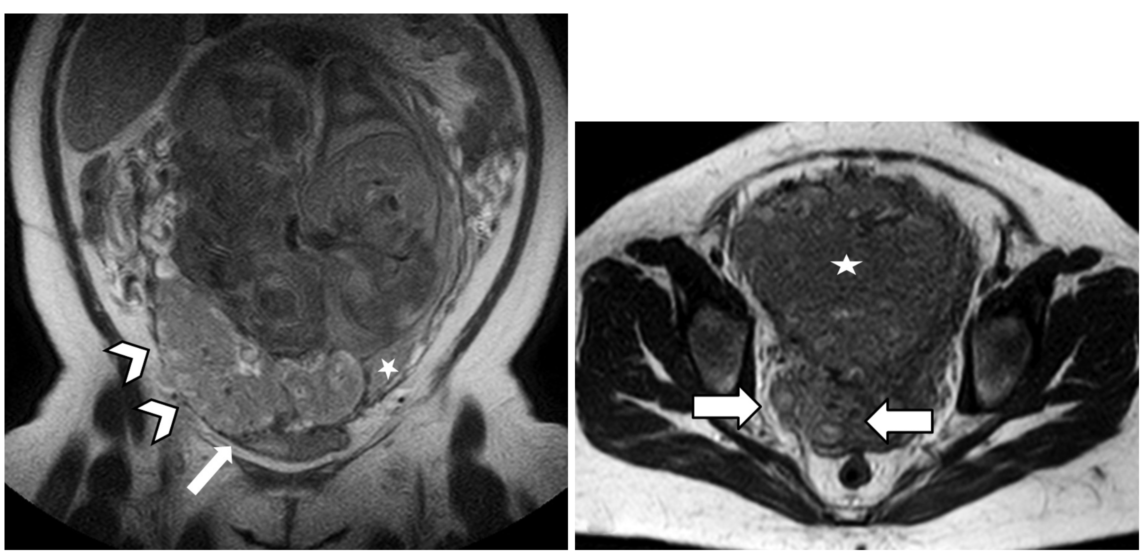
Small, dark intraplacental bands may be observed in mature non-invasive placenta (> 30 weeks of gestation), typically on the fetal surface of the placenta, whereas abnormal, dark bands usually arise from the maternal surface of the placenta (5, 7-9, 26, 27). Dark intraplacental bands with no PAS can be seen in pregnant patients with placental infarction and intervillous thrombus (21). Placental infarctions are common in patients with risk factors for placental insufficiency, such as a maternal history of smoking (36, 37).

Bladder Varices

Bladder varices can mimic focal bulging of the uterine contour in PAS (1, 10). A helpful MRI technique is DWI, which shows low signal intensity of bladder varices, while the placental bulge shows high signal intensity on DWI. The varices may mimic disorganized vascularity around the bladder in PAS; however, there is associated subplacental and intraplacental neovascularization and other findings of invasive placenta in PAS (1, 10).

Focal Bulge at the Maternal Umbilicus

Late in the third trimester of pregnancy, the rectus



A B

Fig. 11. Extrauterine invasion.
A. A 32-year-old woman at 34 weeks gestation. Coronal T2 SSFSE shows bladder invasion (arrow) and direct visualization of placental tissue beyond the uterus (arrowheads). Normal myometrium at left-lateral aspect of uterus is seen (asterisk). **B.** 34-year-old woman at 35 weeks gestation. Axial T2 SSFSE shows right-parametrial invasion (arrows) by placental tissue. The signal intensity is similar to that of the intrauterine placenta (asterisk).

 https://doi.org/10.3348/kjr.2020.0580

A B

Fig. 12. Potential imaging pitfalls.
A. A 28-year-old woman at 34 weeks gestation. Sagittal T2 SSFSE shows few small intraplacental dark bands (thin arrow) and uniform few subplacental flow voids (arrowheads). These vessels may be confused with abnormal serosal vascularity. Normal tapering angular edge (thick arrow) and no heterogeneous placenta are identified. This patient has no evidence of PAS at time of delivery. **B.** A 30-year-old woman at 29 weeks gestation. Sagittal T2 SSFSE shows prior cesarean scar with skin incision (arrow). There is focal thinning of myometrium in this area, which often results from superficial myometrial attachment without myometrial invasion (arrowheads). Complete placenta previa (asterisk) is seen with no intraplacental dark band and no placental heterogeneity.

sheath may separate and cause focal bulging of the anterior aspect of the myometrium (Fig. 1) (10). This may cause PAS diagnosis-related confusion, but a normal appearance of the myometrium and a normal placenta-myometrial interface argues against PAS.

Loss of Retroplacental T2 Dark Zone

The retroplacental T2 dark zone is frequently absent in normal, near-term pregnancy, so it is regarded as being an unreliable sign or insufficiently sensitive (Fig. 2), even when the MRI scan plane was performed perpendicular to the placenta-myometrial interface. Reliance on this sign only can lead to a false-positive interpretation (10, 11, 24).

Myometrial Thinning in Region of Prior Cesarean Section Scar

Focal myometrial thinning beneath the placenta in the lower uterine segment in patients with a prior cesarean section scar with no presence of bulging of external myometrial contour, often results from superficial myometrial attachment (accreta) without myometrial invasion (Fig. 12) (5, 7-9, 26, 27).

Step 8. Uterine Sector

In the majority of placenta percreta cases, the urinary bladder is the most frequent organ of invasion. Palacios-Jaraquemada (38) proposed topography on sagittal MRI that divides the anterior placental invasion into two sectors, with a plane drawn perpendicular to the center of the so-called upper bladder axis (38-41). The S1 uterine sector is situated in the uterine body and the S2 uterine sector is mainly located in the lower uterine segment or below it. S1 PAS generally involves easy access and quick hemostasis, whereas S2 PAS is irrigated by deeply located vessels (Fig. 13) (38-41). Knowledge of the uterine sector and vascular areas i.e., the uterine body (S1 sector), and of the lower uterus, cervix, and upper vagina (S2 sector); provides useful information regarding

https://doi.org/10.3348/kjr.2020.0580

Korean Journal of Radiology
KJR

Fig. 13. A 28-year-old woman at 35 weeks gestation. Sagittal T2 SSFSE shows two uterine sectors of placental invasion (S1 and S2) with demarcation using upper bladder axis (plane perpendicular to center of bladder). Few posteriorly located intraplacental dark bands are observed in the S2 sector (arrow).

potential technical difficulties at operation. It also allows for planning of hemostatic-method and avoids damage to the adjacent ureters. Moreover, because MRI permits the total volume of invasion to be examined in multiple slices and spatial positions, it can influence the surgical approach (40-42). Chen et al. (43) adopted the topography developed by Palacios-Jaraquemada (38) to establish correlations between the invasion topography and maternal morbidity. The researchers found that the rates of cesarean hysterectomy, ureteral injuries, ICU admission, and the amount of blood transfusion in placenta percreta with S2 sector invasion, were higher than the corresponding values for S1 sector invasion (p value < 0.05).

Fail-Safe Check before Final Step

Before proceeding to the final step, there are some diagnostic clues that need to be acknowledged:

- Placental bulge and uterine serosal hypervascularity are useful MRI features for differentiating placenta percreta and increta from placenta accreta (7, 9-11).

- The more extensive and invasive the placenta, the more distorted the vascular architecture should be (5, 7-9, 27).

- Marked heterogeneity and intraplacental dark bands in a T2-weighted image are the most sensitive MRI signs for detecting PAS (1, 10, 11).

- In cases with the absence of placental heterogeneity or dark intraplacental banding, evaluation of the uterine contour and myometrial changes may be helpful for diagnosing PAS (5, 7-9).

- The presence of two or more MRI features increases the reliability of a PAS diagnosis (5, 7-9).

- Regarding the bladder tenting sign, under- or overdistension of the bladder may cause a false interpretation of this sign.

- Some imaging planes can lead to a false-positive diagnosis of PAS due to the curved shape of the uterus. Suspicious findings should be confirmed in more than one imaging plane.

- MRI should not be used alone. A combined study that includes both MRI and US, in addition to the clinical context, must be performed.

Step 9. Additional Information and Treatment Planning

Apart from all of the MRI information of PAS from Steps 1–8; the other clinically relevant findings that need to be described are the fetal position, cervical length, status of the cervical internal os (i.e., placental protrusion sign or protrusion of the placental tissue into a cervical internal os), and incidental extrapelvic findings (44, 45). All of these factors will affect the surgical planning, surgical technique, organ mobilization, site of the surgical incision, and need for preoperative uterine artery embolization (46, 47). Adjacent non gynecological structural involvement, such as rectal involvement or deep major vessel involvement, should be reported since it will need to be managed by a multidisciplinary surgical team. Due to the intrapartum and postpartum bleeding risks, centers taking care of these patients should have the ability to rapidly provide blood products for transfusion.

The timing of delivery may have a major impact on the maternal and perinatal outcomes. O'Brien et al. (48) reported that after 35 weeks, 93% of patients with PAS, experience a hemorrhage necessitating delivery. Warshak et al. (49) reported that planned delivery at 34–35 weeks of gestation did not significantly increase morbidity. Patients with a prenatal diagnosis of PAS should be delivered no later than 36–37 weeks gestation.

Cesarean hysterectomy with the placenta left *in situ* after delivery of the fetus is the standard treatment (14, 48, 50) and is considered suitable management for placenta percreta or the severe form of PAS (25, 51, 52). However, the decision of a subtotal or total hysterectomy should be considered on a case-by-case basis. Though a subtotal hysterectomy may be faster, removal of the entire lower uterine segment and cervix may be required to control bleeding (14, 41, 48-50). For pregnant patients with placenta accreta or the mild form of PAS, a conservative treatment may be chosen: curettage, wedge resection of the affected part of the uterus, ligation of the uterine arteries, and methotrexate treatment to inhibit trophoblast cells and neovascularization (25, 51). However, the American College of Obstetrics and Gynecologists does not recommend conservative management unless there is a strong desire for a future pregnancy; the patient must also be stable hemodynamically and prepared to accept the risks (14). A risk of infection, delayed hemorrhage, and higher mortality rates are expected with conservative management (51). Importantly, patient counseling on the risks should be conducted during delivery planning, regardless of the treatment approach.

CONCLUSION

The increasing incidence of PAS is most likely related to the increasing incidence of cesarean section delivery. The complications of PAS include massive hemorrhage; damage to the uterus, bladder, ureters, and bowel; and the frequent need for a cesarean hysterectomy to control bleeding. The timely and appropriate management of PAS greatly depends on its prenatal diagnosis. MRI is a problem-solving tool that can be employed when US findings are inconclusive. The comprehensive, step-by-step, diagnostic imaging approach described in this article will improve the confidence and ability of the attending radiologist to diagnose PAS, which in turn will accelerate treatment and improve patient outcomes.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

ORCID iDs

Sitthipong Srisajjakul
https://orcid.org/0000-0002-2598-3037
Patcharin Prapaisilp
https://orcid.org/0000-0001-9516-067X
Sirikan Bangchokdee
https://orcid.org/0000-0002-6031-447X

REFERENCES

1. Srisajjakul S, Prapaisilp P, Bangchokdee S. MRI of placental adhesive disorder. *Br J Radiol* 2014;87:20140294
2. Baughman WC, Corteville JE, Shah RR. Placenta accreta: spectrum of US and MR imaging findings. *Radiographics* 2008;28:1905-1916
3. Budorick NE, Figueroa R, Vizcarra M, Shin J. Another look at ultrasound and magnetic resonance imaging for diagnosis of placenta accreta. *J Matern Fetal Neonatal Med* 2017;30:2422-2427
4. Mar WA, Berggruen S, Atueyi U, Sekhon S, Garzon SA, Knuttinen MG, et al. Ultrasound imaging of placenta accreta with MR correlation. *Ultrasound* Q 2015;31:23-33
5. Kilcoyne A, Shenoy-Bhangle AS, Roberts DJ, Sisodia RC, Gervais DA, Lee SI. MRI of placenta accreta, placenta increta, and placenta percreta: pearls and pitfalls. *AJR Am J Roentgenol* 2017;208:214-221
6. Masselli G, Gualdi G. MR imaging of the placenta: what a radiologist should know. *Abdom Imaging* 2013;38:573-587
7. Allen BC, Leyendecker JR. Placental evaluation with magnetic resonance. *Radiol Clin North Am* 2013;51:955-966
8. Balcacer P, Pahade J, Spektor M, Staib L, Copel JA, McCarthy S. Magnetic resonance imaging and sonography in the diagnosis of placental invasion. *J Ultrasound Med* 2016;35:1445-1456
9. Derman AY, Nikac V, Haberman S, Zelenko N, Opsha O, Flyer M. MRI of placenta accreta: a new imaging perspective. *AJR Am J Roentgenol* 2011;197:1514-1521
10. Cuthbert F, Teixidor Vinas M, Whitby E. The MRI features of placental adhesion disorder—a pictorial review. *Br J Radiol* 2016;89:20160284
11. Jha P, Masselli G, Ohliger MA, Pōder L. Nonfetal imaging during pregnancy: placental disease. *Radiol Clin North Am* 2020;58:381-399
12. Einerson BD, Comstock J, Silver RM, Branch DW, Woodward PJ, Kennedy A. Placenta accreta spectrum disorder: uterine dehiscence, not placental invasion. *Obstet Gynecol* 2020;135:1104-1111
13. Tantbirojn P, Crum CP, Parast MM. Pathophysiology of placenta creta: the role of decidua and extravillous trophoblast. *Placenta* 2008;29:639-645
14. Committee on Obstetric Practice. Committee opinion no. 529: placenta accreta. *Obstet Gynecol* 2012;120:207-211
15. Dwyer BK, Belogolovkin V, Tran L, Rao A, Carroll I, Barth R, et al. Prenatal diagnosis of placenta accreta: sonography or magnetic resonance imaging? *J Ultrasound Med* 2008;27:1275-1281
16. Levine D, Hulka CA, Ludmir J, Li W, Edelman RR. Placenta accreta: evaluation with color Doppler US, power Doppler US, and MR imaging. *Radiology* 1997;205:773-776

17. Comstock CH. Antenatal diagnosis of placenta accreta: a review. *Ultrasound Obstet Gynecol* 2005;26:89-96
18. Horowitz JM, Berggruen S, McCarthy RJ, Chen MJ, Hammond C, Trinh A, et al. When timing is everything: are placental MRI examinations performed before 24 weeks' gestational age reliable? *AJR Am J Roentgenol* 2015;205:685-692
19. D'Antonio F, Iacovella C, Bhide A. Prenatal identification of invasive placentation using ultrasound: systematic review and meta-analysis. *Ultrasound Obstet Gynecol* 2013;42:509-517
20. Warshak CR, Eskander R, Hull AD, Scioscia AL, Mattrey RF, Benirschke K, et al. Accuracy of ultrasonography and magnetic resonance imaging in the diagnosis of placenta accreta. *Obstet Gynecol* 2006;108:573-581
21. Varghese B, Singh N, George RA, Gilvaz S. Magnetic resonance imaging of placenta accreta. *Indian J Radiol Imaging* 2013;23:379-385
22. Bonel HM, Stolz B, Diedrichsen L, Frei K, Saar B, Tutschek B, et al. Diffusion-weighted MR imaging of the placenta in fetuses with placental insufficiency. *Radiology* 2010;257:810-819
23. Morita S, Ueno E, Fujimura M, Muraoka M, Takagi K, Fujibayashi M. Feasibility of diffusion weighted MRI for defining placental invasion. *J Magn Reson Imaging* 2009;30:666-671
24. Kim JA, Narra VR. Magnetic resonance imaging with true fast imaging with steady-state precession and half-fourier acquisition single-shot turbo spin-echo sequences in cases of suspected placenta accreta. *Acta Radiol* 2004;45:692-698
25. Oyelese Y, Smulian JC. Placenta previa, placenta accreta, and vasa previa. *Obstet Gynecol* 2006;107:927-941
26. Rahaim NS, Whitby EH. The MRI features of placental adhesion disorder and their diagnostic significance: systematic review. *Clin Radiol* 2015;70:917-925
27. Lax A, Prince MR, Mennitt KW, Schwebach JR, Budorick NE. The value of specific MRI features in the evaluation of suspected placental invasion. *Magn Reson Imaging* 2007;25:87-93
28. Bourgioti C, Zafeiropoulou K, Fotopoulos S, Nikolaidou ME, Theodora M, Daskalakis G, et al. MRI prognosticators for adverse maternal and neonatal clinical outcome in patients at high risk for placenta accreta spectrum (PAS) disorders. *J Magn Reson Imaging* 2019;50:602-618
29. Elsayes KM, Trout AT, Friedkin AM, Liu PS, Bude RO, Platt JF, et al. Imaging of the placenta: a multimodality pictorial review. *Radiographics* 2009;29:1371-1391
30. Leyendecker JR, DuBose M, Hosseinzadeh K, Stone R, Gianini J, Childs DD, et al. MRI of pregnancy-related issues: abnormal placentation. *AJR Am J Roentgenol* 2012;198:311-320
31. Konstantinidou AE, Bourgioti C, Fotopoulos S, Souka E, Nikolaidou ME, Zafeiropoulou K, et al. Stripped fetal vessel sign: a novel pathological feature of abnormal fetal vasculature in placenta accreta spectrum disorders with MRI correlates. *Placenta* 2019;85:74-77
32. Alamo L, Anaye A, Rey J, Denys A, Bongartz G, Terraz S, et al. Detection of suspected placental invasion by MRI: do the results depend on observer' experience? *Eur J Radiol* 2013;82:e51-e57
33. Konijeti R, Rajfer J, Askari A. Placenta percreta and the urologist. *Rev Urol* 2009;11:173-176
34. Goergen SK, Posma E, Wrede D, Collett J, Pyman J, Alibrahim E, et al. Interobserver agreement and diagnostic performance of individual MRI criteria for diagnosis of placental adhesion disorders. *Clin Radiol* 2018;73:908.e1-908.e9
35. Bourgioti C, Zafeiropoulou K, Fotopoulos S, Nikolaidou ME, Antoniou A, Tzavara C, et al. MRI features predictive of invasive placenta with extrauterine spread in high-risk gravid patients: a prospective evaluation. *AJR Am J Roentgenol* 2018;211:701-711
36. Lim PS, Greenberg M, Edelson MI, Bell KA, Edmonds PR, Mackey AM. Utility of ultrasound and MRI in prenatal diagnosis of placenta accreta: a pilot study. *AJR Am J Roentgenol* 2011;197:1506-1513
37. Holloway AC, Salomon A, Soares MJ, Garnier V, Raha S, Sergent F, et al. Characterization of the adverse effects of nicotine on placental development: in vivo and in vitro studies. *Am J Physiol Endocrinol Metab* 2014;306:E443-E456
38. Palacios-Jaraquemada JM. Efficacy of surgical techniques to control obstetric hemorrhage: analysis of 539 cases. *Acta Obstet Gynecol Scand* 2011;90:1036-1042
39. Palacios Jaraquemada JM, Pesaresi M, Nassif JC, Hermosid S. Anterior placenta percreta: surgical approach, hemostasis and uterine repair. *Acta Obstet Gynecol Scand* 2004;83:738-744
40. Palacios-Jaraquemada JM. Diagnosis and management of placenta accreta. *Best Pract Res Clin Obstet Gynaecol* 2008;22:1133-1148
41. Palacios-Jaraquemada JM, Bruno CH, Martín E. MRI in the diagnosis and surgical management of abnormal placentation. *Acta Obstet Gynecol Scand* 2013;92:392-397
42. Clausen C, Lönn L, Langhoff-Roos J. Management of placenta percreta: a review of published cases. *Acta Obstet Gynecol Scand* 2014;93:138-143
43. Chen X, Shan R, Song Q, Wei X, Liu W, Wang G. Placenta percreta evaluated by MRI: correlation with maternal morbidity. *Arch Gynecol Obstet* 2020;301:851-857
44. Liu W, Chen X, Sun C, Wei X, Wang G, Shan R. Morphological evaluation of cervix using MRI at 32 to 36 weeks of gestation. Findings for predicting invasive placenta previa. *Medicine (Baltimore)* 2018;97:e13375
45. Woodward PJ, Kennedy A, Einerson BD. Is there a role for MRI in the management of placenta accreta spectrum? *Curr Obstet Gynecol* Rep 2019;8:64-70
46. Kayem G, Davy C, Goffinet F, Thomas C, Clément D, Cabrol D. Conservative versus extirpative management in cases of placenta accreta. *Obstet Gynecol* 2004;104:531-536
47. Sivan E, Spira M, Achiron R, Rimon U, Golan G, Mazaki-Tovi S, et al. Prophylactic pelvic artery catheterization and embolization in women with placenta accreta: can it prevent cesarean hysterectomy? *Am J Perinatol* 2010;27:455-461

48. O'Brien JM, Barton JR, Donaldson ES. The management of placenta percreta: conservative and operative strategies. *Am J Obstet Gynecol* 1996;175:1632-1638
49. Warshak CR, Ramos GA, Eskander R, Benirschke K, Saenz CC, Kelly TF, et al. Effect of predelivery diagnosis in 99 consecutive cases of placenta accrete. *Obstet Gynecol* 2010;115:65-69
50. Royal College of Obstetricians and Gynaecologists. Placenta praevia, placenta praevia accreta and vasa praevia: diagnosis and management. Green-top guideline no. 27. London: Royal College of Obstetricians and Gynaecologists, 2011
51. Miller DA, Chollet JA, Goodwin TM. Clinical risk factors for placenta previa-accreta. *Am J Obstet Gynecol* 1997;177:210-214
52. American College of Obstetricians and Gynecologists. ACOG Practice Bulletin: Clinical Management Guidelines for Obstetrician-Gynecologists Number 76, October 2006: postpartum hemorrhage. *Obstet Gynecol* 2006;108:1039-1047