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REVIEW

MRI evaluation of invasive placenta: "Cool" answers to radiologists' "hot" questions

Charis Bourgioti, Konstantina Zafeiropoulou, Lia Angela Moulopoulos

Department of Radiology, National and Kapodistrian University of Athens, School of Medicine, Areteion Hospital, Greece

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ABSTRACT

During the last decades, the incidence of invasive placenta has risen significantly, probably due to the increased rate of caesarian delivery. Invasive placenta may cause massive intra-or postpartum hemorrhage; therefore, prenatal diagnosis of the presence and extent of myometrial invasion or extrauterine placental spread is critical for optimal management. Sonography is the imaging modality of choice for the evaluation of abnormal placenta; MRI performs equally well and can be used as a reliable alternative in cases of equivocal sonographic findings. Indications for MRI include evaluation of a posteriorly located placenta and the need for precise delineation of placenta percreta for pre-delivery planning. Suspicious MRI findings for abnormal placentation include, marked placental heterogeneity, low T2 signal intraplacental bands, extensive intraplacental vascularity, focal uterine bulge, myometrial thinning or disruption with loss of utero-placental interface, bladder 'tenting' and the placental protrusion sign. Currently, there is no official standardization of MRI protocols and there are no large series addressing the interobserver variability for the evaluation of invasive placenta. The aim of this review is to report current literature data regarding MRI assessment of invasive placenta in an attempt to familiarize radiologists with the 'hot' topic of abnormal placentation.

KEY WORDS

placenta accreta; placenta percreta; placenta increta; ultrasound (US); Magnetic Resonance Imaging (MRI)

CORRESPONDING AUTHOR, GUARANTOR

Charis Bourgioti, MD. Department of Radiology, National and Kapodistrian University of Athens, School of Medicine, Areteion Hospital, 76 Vassilisis Sofias Ave., 11528, Athens, Greece
E-mail: charisbourgioti@yahoo.com

1. Introduction

The term "placenta" originates from the Greek word plakuos, which means "flat cake". Indeed, placenta is the "cake" for the fetus, as it is responsible for its nutrition and its respiratory and excretory function. Prenatal evaluation of the abnormal placenta is a "hot" topic for both gynecologists and radiologists; early identification of invasive placenta and accurate preoperative diagnosis regarding the degree of myometrial invasion and extrauterine spread, are critical for optimal management.

Magnetic Resonance Imaging (MRI) may provide important information for pre-delivery planning in patients with invasive placenta; however, accurate interpretation of the MRI appearance of invasive placenta requires expertise. The aim of this study is to review current literature data regarding MRI diagnostic performance for the evaluation of invasive placenta and to familiarize radiologists with common MRI features of abnormal placentation.

We have conducted a literature search using MEDLINE (PubMed) Library. Applied key words included: Invasive placenta; placenta accreta; placenta increta; placenta percreta; MRI; US. The search period extended from July 1985 to March 2016. Prospective or retrospective original research studies and review articles with or without meta-analysis data were reviewed; selection of the studies was performed by consensus from all authors and it was based on the presence of the following criteria: Appropriate study design, adequate study population (>20 patients), use of clear diagnostic evidence, reliable statistical data and reproducibility of the results. A total of 33 studies were finally included in our review report.

2. Clinical information

Invasive placenta is a serious pregnancy condition, characterized by a defect of the desidua, through which the fetal trophoblast (chorionic villi) extends to the myometrium. There are three types of invasive placenta, based on extent of myometrial invasion: (a) placenta accreta (the least invasive type), where the villi attach to the myometrium and may superficially invade it, (b) placenta increta, where the villi partially invade the myometrium and (c) placenta percreta, where the villi completely penetrate the myometrium, reaching to the uterine serosa, with or without invasion of the surrounding extrauterine tissues.

Well-established risk factors associated with invasive placenta include a previous Cesarean section (C-section), presence of placenta previa (i.e. location of the placenta at the lower uterine segment, within 2 cm from the internal cervical os; two main types of placenta previa are defined: Complete previa, when placenta completely covers the internal os and marginal previa, when the leading edge of the placenta is less than 2 cm from the internal os and advanced maternal age (>35 years). Minor risk factors associated with invasive placenta include Asherman's syndrome (i.e. the presence of adhesions within uterine cavity), uterine fibroids [1] and history of uterine surgeries, including curettage, abortions or myomectomy [2].

Invasive placenta may spontaneously develop in a small percentage (0.4%) of the general population. Its incidence increases significantly (5%) when placenta previa is present. If the patient also has a history of a single C-section, the incidence rises to 24%; when placenta previa is associated with multiple prior (>3) C-sections, the risk for abnormal placentation becomes extremely high (67%) [3].

Invasive placenta may be a life-threatening condition during delivery, because of the increased risk of massive intra- or postpartum haemorrhage, as the abnormal placenta is strongly attached to the myometrium and cannot be completely separated from the uterus, potentially causing uncontrollable bleeding. Massive blood loss (>3-5 l) may cause disseminated intravascular coagulopathy (DIC), renal failure, adult respiratory distress syndrome (ARDS) and death. Reported maternal mortality rates due to invasive placenta reach 7% [4-7]. Therefore, accurate prenatal diagnosis becomes an important issue for clinicians, in order to appropriately schedule delivery and minimize maternal and neonatal risks. Patients with invasive placenta are usually scheduled for C-section at 34-35 weeks, in an attempt to limit the risk of fetal lung immaturity.

The management of placental invasion requires a multidisciplinary approach with participation of a well-trained surgical team (e.g. gynecologists, urologists), dedicated anesthesiologists and pediatricians. Blood products should be readily available. Interventional radiology techniques, such as perioperative internal iliac artery occlusion, may be employed, in order to reduce blood loss during surgery and subsequent need for transfusion [8, 9].

3. Discussion

3.1 Sonography: Is it enough for the diagnosis of invasive placenta?

Transabdominal gray scale and Color Doppler sonography is the first-line imaging modality used to evaluate

invasive placenta, since it is a widely available, low-cost imaging method, which can be safely applied to the pregnant patient, due to lack of ionizing radiation. Typical ultrasonography (US) screening for evaluation of the placenta is performed during week 18-20. In cases of placenta previa and prior C-section, the presence of abnormal placentation should be highly suspected. Evaluation of the lower uterine segment may be difficult with conventional sonographic examination; a high-frequency transducer can be used for more detailed imaging. A transvaginal approach may be helpful in some cases, for better evaluation of the myometrium of the anterior lower uterine segment, the morphology of the placenta, and the evaluation of the myometrial-placental interface [7, 10].

Sonographic features indicative of invasive placenta were initially described by Finberg and Williams [11]. Highly specific (>80% specificity) sonographic signs of abnormal placentation include: Loss of the retroplacental hypoechoic zone (i.e. the venous network within the stratum spongiosum of the desidua), presence of large and irregular dilated intra-placental vascular spaces (commonly known as placental lacunae) observed as early as at the 15th week of gestation, extensive vascularization in the utero-placental interface, and myometrial thinning (<1 mm) [10, 12]. In the case of placenta percreta with extrauterine spread, US may demonstrate a focal uterine bulge with a vascular mass extending beyond the uterus, marked thinning or loss of the normal utero-bladder interface and presence of a prominent vascular network between the uterine serosa and the bladder. Recently, Shih et al. [13] reported three-dimensional (3D) power Doppler criteria for the diagnosis of invasive placenta, focused on the evaluation of the utero-placental vascularity pattern; extreme intraplacental vascularity and presence of numerous, tortuous vessels with a chaotic pattern (mimicking the neovascularity observed in ovarian malignancies), located at the base of the placenta proved to be accurate signs of invasive placenta [13].

The overall diagnostic accuracy of sonography for the evaluation of the placenta is high, with reported sensitivity (SE) and specificity (SP) values equal to 85.7% and 88.6%, respectively [14]. Difficulties in the evaluation of invasive placenta include posterior location, presence of a postoperative uterine scar (as it is often associated with an acoustic shadow) and poor imaging quality due to patient's body habitus or operator's inexperience. Sonographic evaluation of extension of the placenta to the surrounding tissues and organs (e. g. parametrial space, bladder and bowel) may be limited because of their location deep in the pelvis and the transducer's relatively small field of view.

3.2. MR imaging for evaluation of the placenta: When is it needed?

MRI is an excellent imaging modality for the evaluation of pelvic tissues, due to its inherent ability to discriminate between tissues with similar consistencies. MRI can accurately assess the location of the placenta in the uterus, although this is easily evaluated with sonography, with the exception of a posteriorly located placenta [15].

Literature data support the important role of MRI for delineating the overall topography of invasive placenta prior to surgery. Lateral extension into the parametrial fat is rather uncommon (16%); however, such information is important to optimize surgery and avoid ureteral injury [16]. MRI is better than sonography for the evaluation of the periuterine/parametrial fatty tissues and the adjacent pelvic organs, (urinary bladder and bowel), due to the better contrast resolution and larger field of view.

MRI is currently considered a reliable alternative to US, when findings of the latter are equivocal. Dwyer et al. found both MRI and ultrasound complementary to each other, when one of the two modalities had inconclusive results [15]; according to the same study, no cases where found where both modalities failed to establish a diagnosis of invasive placenta. Therefore, some authors propose a routine 2-stage protocol for better pre-delivery planning in cases of invasive placentation [17]. This protocol includes an initial evaluation with US (which most of the times effectively establishes or rules out invasive placenta), followed by pelvic MRI, which confirms the diagnosis and provides detailed images of placental extension.

Even though more prospective studies need to be performed, the diagnostic accuracy of both MRI and US for the identification of abnormal placenta is comparable. According to a large meta-analysis conducted by Antonio et al. [14] involving 18 strictly selected studies, with a total of 1,010 pregnancies at risk for invasive placentation, there was no significant difference in diagnostic ability between US and MRI, for the detection of invasive placentation. SE and SP values for detecting invasive placenta were 90.2% and 88.2%, respectively for MRI and 85.7% and 88.6%, respectively for US. In another, recently published review, meta-analysis data collected from

13 studies, showed 83% SE and 95% SP for US, and 82% SE and 88% SP for MRI; the authors once again concluded that the diagnostic accuracy of the two modalities for the identification of invasive placenta is equally high [18].

3.3. Normal *vs.* invasive placenta: Discriminative features on MRI

Knowledge of normal placental anatomy is helpful to discriminate between normal and invasive placenta. The placenta has two surfaces, fetal and maternal. The fetal surface (known as the chorionic plate) is where the umbilical cord inserts. The umbilical vessels divide to chorionic vessels, which form, deep in the placenta, the vascular network of the villous trees. Chorionic vessels are practically not visible deep within the placenta; however, few, less than 5 mm thick vascular branches, may be seen on MRIs of normal, non-invasive placentas. In the maternal surface, spiral arteries are located at the myometrium-placental interface, parallel to the villous tree of the chorionic arteries and perpendicular to the decidual surface. Sub-placental vascularity is present to some degree and it manifests as areas of signal flow voids on MRI [19].

The presence of serpentine, >6 mm vessels (with flow voids) deep within the placenta, is a reliable sign of intraplacental abnormal vascularity. This feature is usually more obvious on T2-weighted sequences and it represents abnormal, dilated vascular lacunae; extensive vascular disorganization may be directly correlated to the extent of placental invasiveness [19].

The appearance of the placenta changes during the course of pregnancy because of placental maturation. Prior to the 23rd week of gestation, the placenta is usually demonstrated as a uniformly homogeneous soft tissue structure of low-to intermediate T2 signal (**Fig. 1**). Between 24th-31st weeks of gestation, it may become less uniform on MRI, as placental lobules tend to increase in number and placenta septa (see next paragraph) become more obvious. After the 32nd week of gestation, the placenta's MR signal appears even more inhomogeneous [15, 20]. Therefore, MRI for placental evaluation should be ideally performed before the 30th week of gestation.

The maternal surface of the placenta consists of cotyledons (or placental lobules) and each of them contains several villi; placental lobules are surrounded by clefts and septa of connective tissue [21]. Normal placental septa can be seen on T2-weighted MR images obtained after the 24th week of gestation (when lobules become marked), especially with 3T magnets, as smooth, thin linear bands of low T2 signal within the placenta. On the contrary, the presence of thick (>2 cm), low T2 signal intensity bands of nodular or linear morphology within the placenta, randomly distributed, is a feature highly suggestive of invasive placenta. The sign of intraplacental T2 dark bands possibly represents pathological fibrin deposition within the placental tissue (**Fig. 2**) [22].

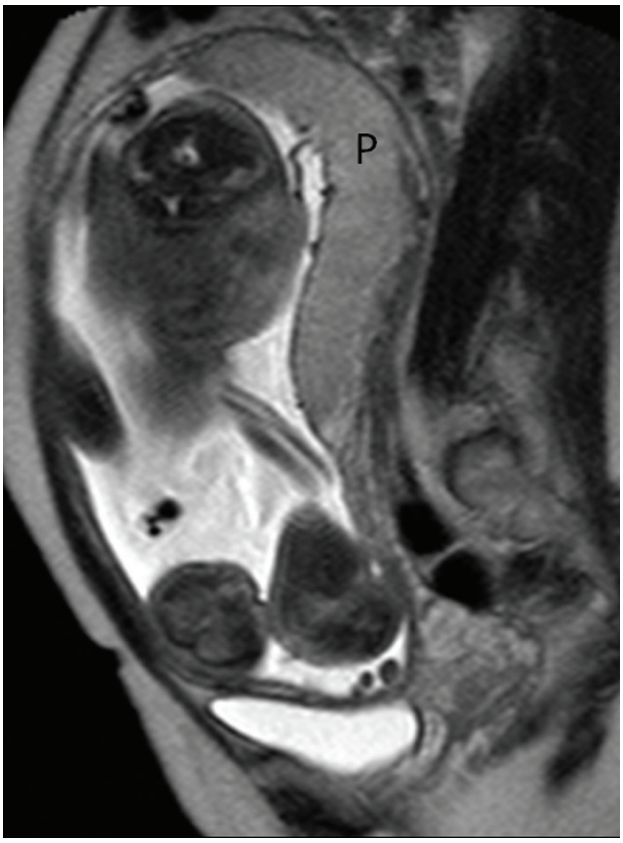
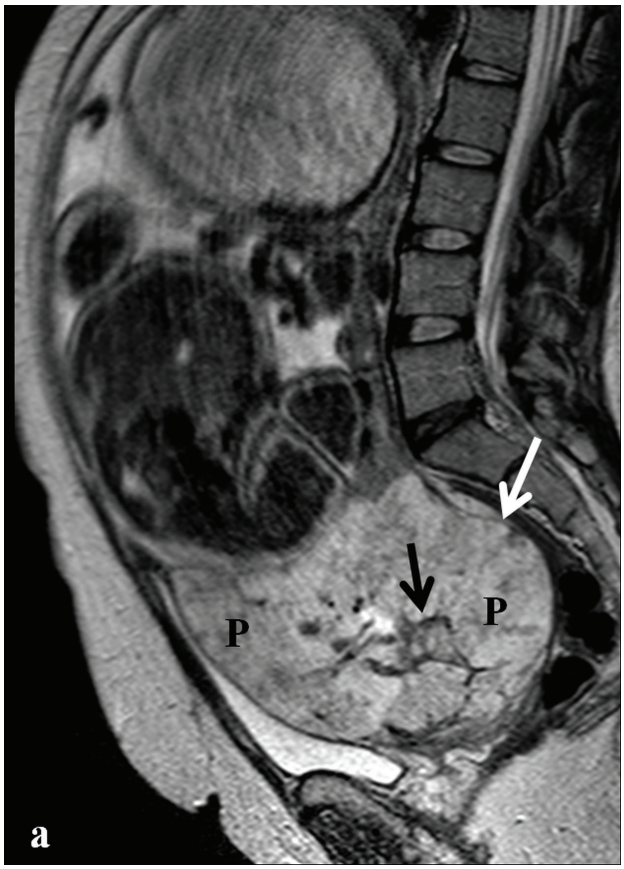


Fig. 1. *Sagittal half-Fourier single-shot TSE T2-W MR image of a 33-year-old woman with normal placenta at week 24 of gestation. The placenta (p) is located >2 cm away from the internal cervical os and it has intermediate, homogeneous signal intensity*

During pregnancy, the uterus retains its normal pear-shaped morphology. A placental bulge is another sign of abnormal placentation (**Fig. 3**). It is defined as a focal protrusion of the uterine contour (with or without disruption of the myometrium) with the lower uterine segment being wider than the fundus (reverse to normal). When a placental bulge is present, invasion of neighboring tissues, typically the bladder, should be suspected [22-24]. When placenta percreta is present, a characteristic elongation of the bladder dome ("tenting") may be



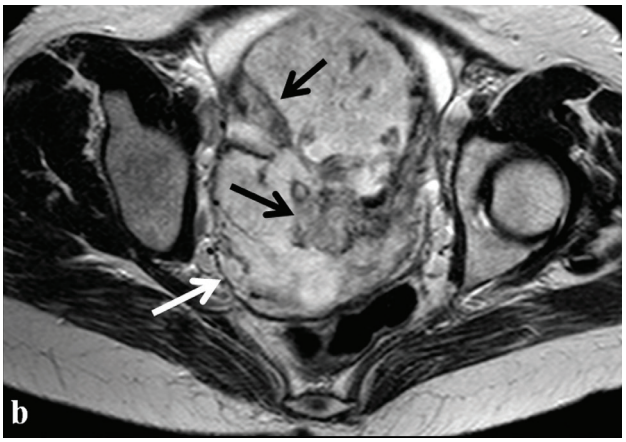
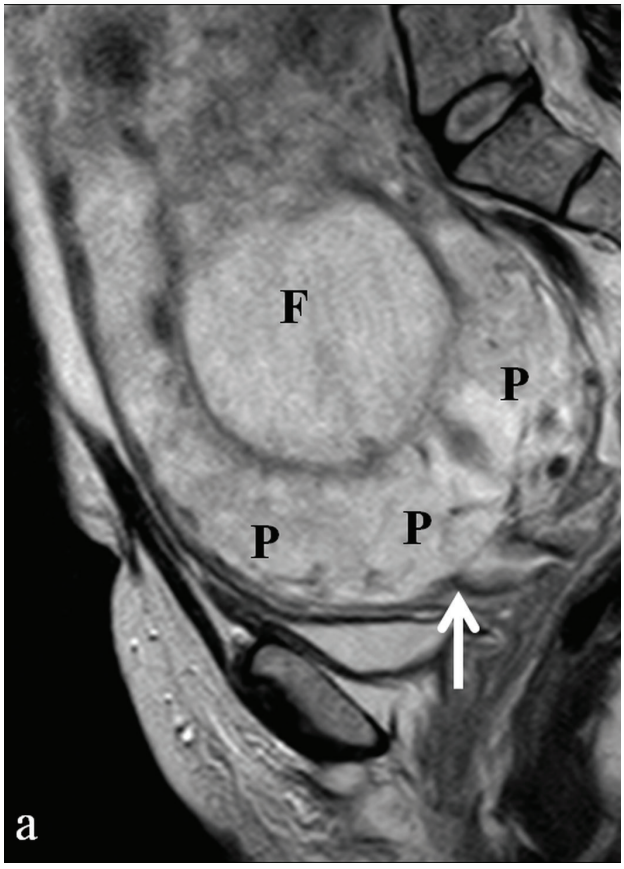


Fig. 2. (a) *Sagittal T2-W MR image of a 29-year-old patient with invasive placenta at week 34 of gestation. The placenta (P) fills the lower uterine segment and appears heterogeneous with thick dark intraplacental bands (black arrows). Extensive myometrial thinning is present as well as a focal bulge of the posterior uterine contour (white arrow)*
(b) *Corresponding axial T2-W MR image clearly demonstrates T2 dark bands (black arrows) and focal uterine bulge on the right (white arrow). Hysterectomy was performed during delivery due to massive hemorrhage; specimen examination confirmed the MRI diagnosis of placenta percreta*



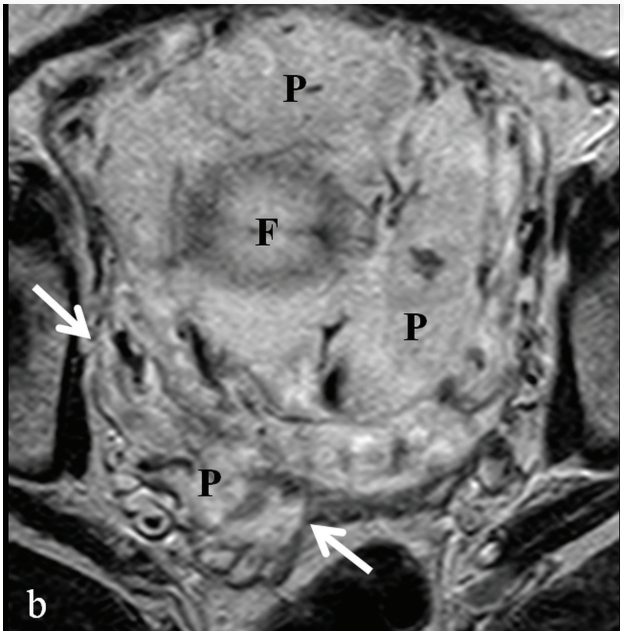


Fig. 3. (a) *Sagittal T2-W MR image of a 36-year-old patient with invasive placenta at week 34 of gestation. Placental tissue (P) completely covers the internal cervical os (arrow)*
(b) *Corresponding T2-W MR image in the axial plane shows placental extension within the parametrial fat at the right posterior aspect of the uterus (arrows). Placenta percreta with extrauterine parametrial spread was confirmed intraoperatively. F: fetus*

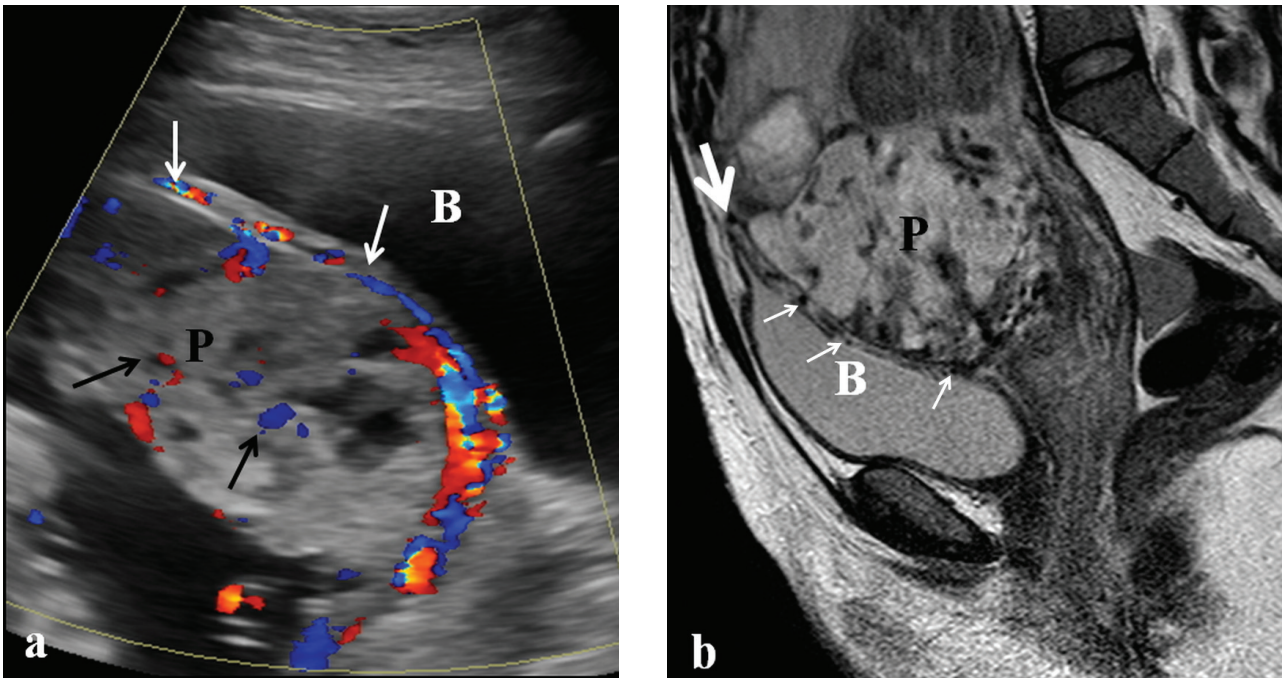


Fig. 4. *A 34-year-old patient with invasive placenta at week 24 of gestation. Color Doppler examination* ***(a)*** *shows increased vascularization deep in the placenta (black arrows) and at the utero-bladder interface (white arrows). Corresponding sagittal T2-W MR image* ***(b)*** *shows marked placental heterogeneity, with multiple vascular structures extending to the bladder wall (thin white arrows) and 'tenting' of the bladder dome (thick white arrow). Placenta percreta with bladder invasion was confirmed at surgery. B: bladder, P: placenta*

seen and has been shown to strongly correlate with bladder invasion (**Fig. 4**). Other signs suggestive of bladder involvement include loss of the fat plane between the placenta and the bladder wall and presence of an abnormal vascular network in the utero-bladder space [22, 24].

We already mentioned that, during the course of pregnancy, the normal placenta shows some degree of parenchymal heterogeneity, which increases with gestational age [20]. Although, Lax et al. reported that placenta heterogeneity was more frequently observed in cases of invasive placenta [22], other studies state that placental heterogeneity was not significantly correlated with this diagnosis [25]. Such discrepancies may be explained by the fact that placental heterogeneity is difficult to ascertain because there are no objective or quantitative criteria for defining the term 'heterogeneity'. Characterization of the placenta as heterogeneous is rather subjective and for most authors depends on the presence or absence of abnormal, dark bands on T2-weighted MR images [19], areas of hemorrhage/infarction (in that case, MR signal depends on the age of hemorrhage), and/or intraplacental abnormal vascularity [19, 22].

The myometrium becomes thinner as the pregnancy progresses. Normal myometrium has a 'three layer' appearance ('sandwich' like). The outer and inner layer are demonstrated on MRI as thin, continuous lines of low T2 signal, while the middle layer is thicker, with moderately high signal intensity and often contains multiple flow void signals caused by normal myometrial vessels. The inner layer represents both decidua and the inner myometrium and it corresponds to the uteroplacental interface. The outer layer represents the uterine serosa. For most investigators, uterine myometrial thinning, may, to some degree, be a normal finding in pregnant patients, especially in the third trimester [22, 26, 27]. However, other authors state that any focal or diffuse myometrial thinning or indistinctness, including loss of the thin low T2 utero-placental interface [22, 25, 28], may be a sensitive, although less specific, feature for the diagnosis of invasive placenta (**Fig. 5**). In a recent study by Bour et al. [25], it was found that, thinning or focal loss of the uteroplacental interface was a single, independent MRI variable for the differentiation between normal and invasive placenta; this sign exhibited high diagnostic accuracy (88%) for the diagnosis of invasive placenta.

Placenta previa may cover the internal os, but it does

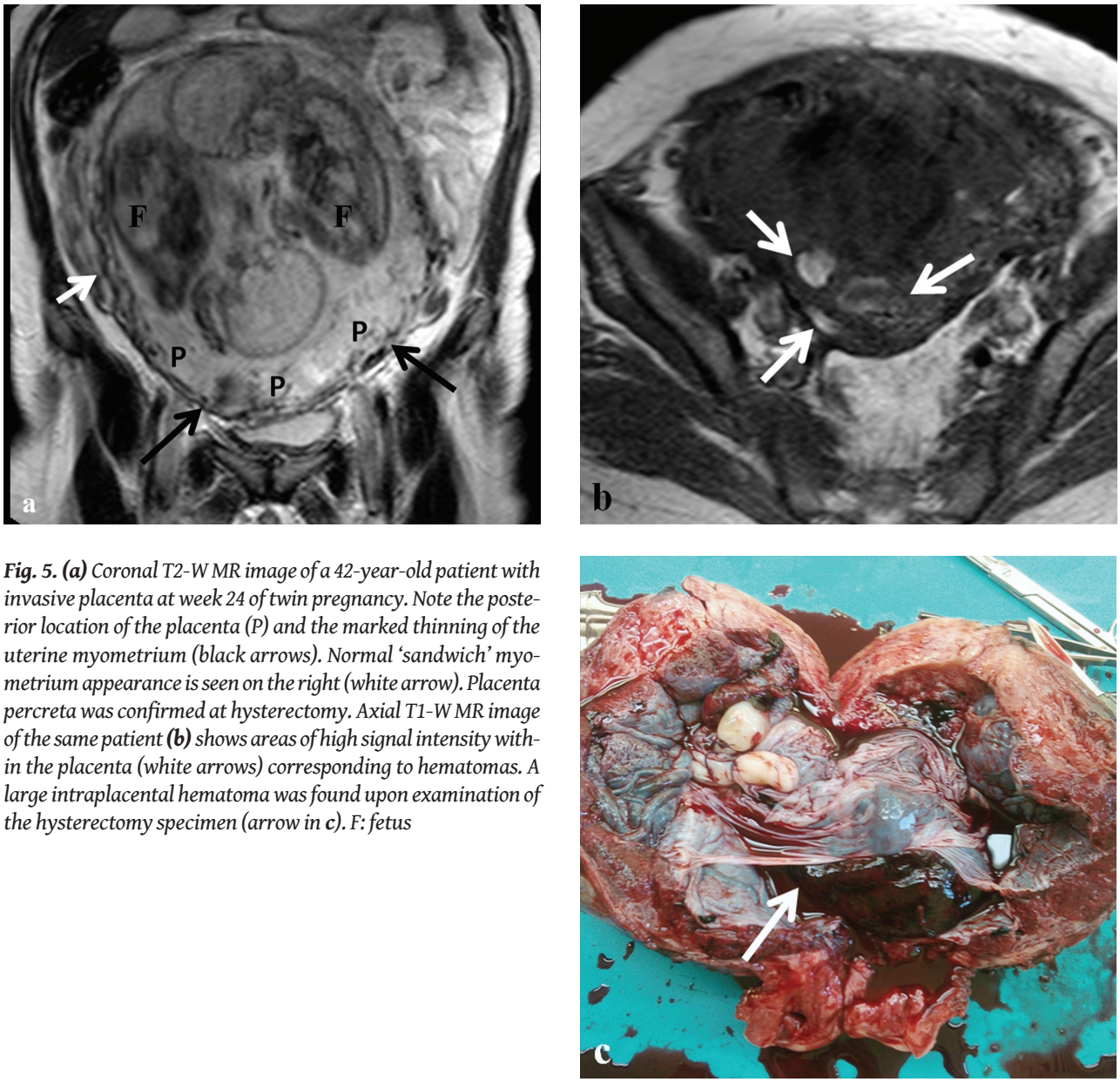


Fig. 5. (a) *Coronal T2-W MR image of a 42-year-old patient with invasive placenta at week 24 of twin pregnancy. Note the posterior location of the placenta (P) and the marked thinning of the uterine myometrium (black arrows). Normal 'sandwich' myometrium appearance is seen on the right (white arrow). Placenta percreta was confirmed at hysterectomy. Axial T1-W MR image of the same patient* ***(b)*** *shows areas of high signal intensity within the placenta (white arrows) corresponding to hematomas. A large intraplacental hematoma was found upon examination of the hysterectomy specimen (arrow in* ***c****). F: fetus*

not protrude inside. When the placenta is invasive, it tends to extent into the internal os. This is the so- called placental protrusion sign [29].

According to data from a large meta-analysis [14], focal myometrial disruption and presence of low T2 intraplacental bands showed 92% and 87.9% SE, respectively, for predicting invasive placentation; 'tenting' of the bladder dome, uterine bulge and placental heterogeneity were less sensitive but more specific signs for placenta percreta with reported SP values equal to 98.6%, 90.2% and 87.7%, respectively.

Assessment of each of the above signs requires caution, since none of the features alone is totally predictive of invasive placenta; interpretation of reported MRI features of invasive placenta, including myometrial thinning and placental heterogeneity, may vary even among experienced readers. Therefore, it is advised that suspicious features for invasive placenta be evaluated in combination, in order to increase the level of diagnostic confidence [14].

3.4 MRI protocol - how do we do it?

Most centers do not advocate any specific preparation before an MRI study for placental evaluation. However, some researchers administer oxygen to the mother, via a nasal cannula, in order to reduce fetal motion. The blad-

der should be moderately full during the MRI examination, for better visualization of the bladder wall.

MRI examinations are usually performed on a 1.5T field-strength unit; a phased-array surface coil is routinely used, whenever possible. According to the present data, no harmful effects have been reported due to the exposure of the developing fetus to 1.5T field-strength. For higher-field-strength systems (3T or more) there are still limited data regarding potential side effects; although no deleterious effects to the fetus have been reported at 3T MR imaging, there is no published literature for long-term side effects in children who have been exposed to such high-field strengths prenatally [30].

There is no uniform consensus regarding the MRI protocol for placental evaluation. In most facilities, MRI acquisitions include axial, coronal and sagittal T2-weighted sequences. Half-Fourier single-shot TSE images and/or T2-weighted true fast imaging with steady-state precession sequences (balanced-FFE) are performed to limit artifacts caused by fetal motion. T2-weighted turbo spin-echo (T2W-TSE) sequences are also obtained for better resolution. Most published protocols for placental evaluation also include sagittal T1-weighted gradient-echo (GRE) in-phase and opposed-phase sequences [31]. At our institution, T1-weighted sequence is routinely used to demonstrate any intraplacental hematomas (**Fig. 5b-c**); T1W fat suppression images may also be obtained to better evaluate sub-or intraplacental vascularity or lacunae. T2-weighted images with fat suppression, may better demonstrate disorganized or chaotic ('bizarre') intraplacental vascularity in patients with placenta percreta . The overall examination time ranges between 15 and 20 min.

The administration of contrast material to pregnant patients is controversial; it is known that gadolinium contrast crosses the placental barrier and can be detected in the amniotic fluid and, subsequently, the fetus. Its effect on the fetus is virtually unknown. Most facilities do not recommend the routine use of gadolinium contrast media in gravid patients. In a limited number of studies, dynamic contrast-enhanced imaging in patients with invasive placenta was performed; authors reported that intravenous contrast material better delineated the placental borders increasing, thus, the specificity of MRI studies [24].

Tips for MRI reports

Step 1: Check the quality of MR images during the exam (repeated acquisitions may be necessary as fetal motion can be responsible for a really poor imaging quality).

Step 2: Locate the placenta. Check if the placenta is previa (complete or marginal); measure the distance from the internal os.

Step 3: Decide whether the placenta is invasive or not by recording the presence of the following features on T2W images:

- Intraparenchymal T2 dark bands
- Hypertrophied (>6 mm) intraplacental vessels in a chaotic distribution
- Marked parenchymal heterogeneity
- Loss of the three 'layer' appearance of the myometrium; if there is focal thinning or loss of the outer myometrium and/or the uteroplacental surface, it should be noted and located
- Focal uterine bulge
- Placental protrusion within the cervical canal
- Remember that MRI features should not be interpreted in isolation but in combination!

Step 4: In case of invasive placenta, try to identify the depth of invasion. Usually there is no clinical usefulness to discriminate between placenta accreta and placenta increta (this is challenging even for experienced radiologists). You should, however, look for signs suggestive of placenta percreta, like presence of vascular tissue in the periuterine/parametrial fat, disruption of the low T2 bladder wall and 'tenting' of the bladder dome. MRI findings of extrauterine extension of the placenta, with invasion of adjacent pelvic structures, prompts for more careful, pre-delivery planning [32, 33].

4. Conclusion

In conclusion, prenatal MRI may accurately diagnose invasive placentation and define extrauterine extent. Ultrasound and MRI have comparable predictive accuracy for identifying invasive placenta and they are complementary to each other. Currently, there is no official standardization of MRI protocols for placental evaluation and there are no large series addressing the variability among MRI readers for the prediction of the extent of abnormal placentation. Larger studies are needed to define diagnostic criteria for the evaluation of invasive placenta and to better assess interobserver variability. R

Conflict of interest:

The authors declared no conflicts of interest.

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