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ABSTRACT

Ultrasound is widely used as the initial diagnostic imaging modality during pregnancy with both high spatial and temporal resolution. Although MRI in pregnancy has long focused on the fetus, its use in placental imaging has greatly increased over recent years. In addition to the possibilities of evaluating function, MRI with a wide field of view and high contrast resolution allows characterization of placental anatomy, particularly in situations that are difficult to specify with ultrasound, especially for suspected placenta accreta. MRI also appears to be a particularly useful examination for the anatomical evaluation of the placenta independent of maternal body habitus or fetal position. Indeed, surprisingly little attention is paid to the placenta in MRI when the indication for the examination is fetal. Thus, some aspects of the placenta seem to us to be important to be recognized by the radiologist and to be described on the MRI report. In this review, we will describe MRI sequences used for, and common features seen in, imaging of i) the normal placenta, ii) abnormal aspects of the placenta that should be identified on MRI performed for fetal reason, and iii) placental anomalies for which placental MRI may be indicated.

Keywords

Placenta; MR imaging; accreta; previa; PAS; magnetic resonance

INTRODUCTION

Imaging of the placenta is an important area of focus in antenatal imaging (1). Because of the potential maternal and/or fetal morbidity associated with placental abnormalities such placental attachment disorders or vascular pathologies, there is a need for accurate antenatal diagnosis (2,3). Ultrasound is widely used as the initial diagnostic imaging modality during pregnancy with both high spatial and temporal resolution. However, it suffers from several technical limitations such as posterior placental localization, interposition of one or more fetuses, oligohydramnios and maternal obesity. The safety of fetoplacental MRI is well established and this imaging modality not operator-dependent has been used in obstetrical imaging for more than twenty years (4–6). Fast multiplanar acquisition, with a wide field of view offers high tissue contrast resolution and permits a complete examination of the fetus and placenta (7,8). While MRI during pregnancy has long focused on the fetus, its utility to placental imaging has greatly increased over recent years (9). In addition to the possibilities of functional MRI of the placenta, widely discussed in this special issue, MRI also appears to be a particularly useful examination for the anatomical evaluation of the placenta independent of maternal body habitus or fetal position. Indeed, surprisingly little attention is paid to the placenta in MRI when the indication for the examination is fetal. Thus, some aspects of the placenta seem to us to be important to be recognized by the radiologist and to be described on the MRI report.

In this review, we will describe MRI sequences used for, and common features seen in, imaging of i) the normal placenta, ii) abnormal aspects of the placenta that should be identified on MRI performed for fetal reason, and iii) placental anomalies for which placental MRI may be indicated.

1.THE NORMAL PLACENTA

The placenta is easily visualized on MRI, with a clear border between placenta and amniotic fluid and a less clear placental-myometrial border. The entire placenta can be imaged at any gestational age, measuring the size, shape and vascular properties across the whole organ.

The placenta is commonly discoid in shape. It attaches to the anterior, fundal, lateral or posterior walls of the uterus, and specifying the position of the placenta in relation to the internal os of the cervix is necessary to determine the delivery route and the risk of bleeding in placenta previa. T2-weighted anatomical imaging shows a relatively homogeneous appearance of the placenta with an intermediate or relatively high T2 signal intensity, giving it a light grey appearance on typical window/levels when viewed in the second trimester (10). The appearance of the placenta changes its appearance in relation to maturation throughout the preganncy. The placenta becomes more lobulated and therefore appears more heterogenous in the third trimester (Figure 1) (11). The normal decidua basalis provides a plane of separation between the placenta and the uterine wall. The normal myometrium on T2-weighted imaging has a tri-layered appearance related to the important vascularization located in the center of the myometrium. Focal myometrial compression is commonly observed anterior to the spine and aorta. The placental-myometrial interface and the architecture of the myometrium cannot be adequately delineated on T1-weighted images due to relatively poor signal and lack of contrast resolution. T2 weighting is the sequence of choice for imaging the placenta. Myometrial contractions which are characterized by transient low signal intensity on T2-weighted images are sometimes observed. The insertion of the umbilical cord can be identified in order to specify eccentric insertions that are less than 1 cm from the placental edge or even velamentous insertions (outside the placental margin) (Figure 1).

2/ ABNORMAL ASPECTS OF THE PLACENTA THAT SHOULD BE IDENTIFIED ON MRI PERFORMED FOR FETAL REASON

It is important to know how to recognize particular aspects of the placenta because its impact the obstetrical management (12). Two situations are to be known: low inserted placentas because of the haemorrhagic risk, and multipartite placentas because they must be searched for vasa praevia that can cause catastrophic fetal haemorrhage.

Low lying Placenta and Placenta previa: 2.9% to 5.2% of pregnancies (13)

The risks factors are previous uterine surgery or cesarean, smoking, advanced maternal age, multiparity, and multiple pregnancies (14). Antenatal diagnosis is important because of the increased risk of PAS, maternal bleeding, prematurity, stillbirth, and neonatal death. It is defined as a placenta that implants within the lower uterine segment and less than 2 cm from the internal cervical os (15). Transvaginal ultrasonography and MR imaging both allow accurate identification of the position of the placenta (16). A sagittal MR sequence oriented in the plane of the cervix is used to assess the placental margin. (Figure 2). Definitive diagnosis of placenta previa should only be made in the third trimester due to the increase in uterine volume during pregnancy and many of low-lying placentas seen in the second trimester resolve by the third trimester. This diagnosis is part of the elements that must be verified by the sonographer, however in case of visualization of a low inserted placenta it must be mentioned on the MRI report.

Vasa previa: 0.46% of pregnancies (17,18)

These vessels are associated with a high rate of perinatal mortality secondary to anoxia because of their compression or by exsanguination due to their rupture before or during labor.

Vasa previa is often associated with low-lying placenta, velamentous cord insertion, bilobed or succenturiate lobed placenta, use of in vitro fertilization, and multiple gestations (19). Ultrasonography with color Doppler is the best modality to visualize vessels crossing the internal cervical os (20). The precise relationship of these structures can be difficult to determine antenatally with ultrasonography and Doppler (21). MRI may suggest the diagnosis of vasa previa when flow voids appear close to the internal cervical os and when this is suspected based on the placental configuration (Figure 2). The vasa previa can be mentioned incidentally on MRI and in this case must be mentioned in the report.

Atypia

Other placental atypia can also be visualized during an MRI examination such as multipartite (22), extrachorionic placenta, haematoma(23), placentomegaly (Figure 3), placental tumors (24) (Figure 4).

Multi partite placenta which is often composed of 2 lobes and separated by a fine bridge of placental parenchyma. In some cases, there is a main mass with one or more small aberrant lobes (cotyledons) connected to it by vessels which is succenturiate placenta. Another configuration is the extrachorionic placenta that is defined by a chorionic plate which is smaller than the basal plate, resulting in an overflow of placental tissue. The most severe form is the circumvallate placenta, in which the placenta has a protruding bulge around a reduced chorionic plate.

Placental thickness can also be of interest in the assessment of specific fetal pathologies such as intrauterine growth restriction, anemia, infections, or chromosomal abnormalities.

Tumors or vacuolar aspects of the placenta can also be identified. The most frequent is the chorioangioma. On MRI chorioangiomas appear isointense to the placenta on T1-weighted

and low to intermediate signal intensity to the placenta on T2-weighted images (25). It can be helpful in cases of large chorioangiomas to differentiate other extremely rare causes of placental mass such as teratomas. MRI of teratomas typically shows the various signal intensities corresponding to intra-tumoral fat, calcifications, and fluid. Other rarer aspects, such as mesenchymal dysplasia (26) or hydatidiform mole can be suspected but MRI is relatively nonspecific. MRI findings are those of diffuse multicystic lesions in the placenta (27).

3/ PLACENTAL ANOMALIES FOR WHICH PLACENTAL MRI MAY BE INDICATED

In certain pathological situations identified by ultrasound, MRI can be an additional help for both diagnosis and obstetrical management. The main clinical situation being PAS.

MRI placental protocol

For the specific analysis of the placenta, the pregnant woman must be comfortable during the MRI exam, which is most often in the supine or lateral decubitus position (28). In our experience, we find it most helpful to perform MRI of the placenta with a distended/full bladder in order to optimize visualization of the bladder serosal margins as a T2 hypointense interface.

Most routine clinical MRI examinations in pregnancy are performed on 1.5T systems. Acquisitions are made using commonly available surface array coils (body or cardiac). The sequences used are carried out in order to reduce the energy deposition, reflected as specific absorption rate (SAR), as much as possible with adapted fields of view, matrices of roughly 256 by 224 and limited flip angles.

The protocols used are based on ultra-fast acquisitions with excellent anatomical detail of the structures on SSFP (Steady State Free Precession) T2/T1 weighted

images, (e.g. Fiesta, Trufisp), more T2 weighting on Single Shot Fast Spin Echo images (e.g. SSFSE, Haste), and also T1 weighting on gradient echo images (e.g. SPGR, Flash) which can help identify haemorrhagic products with their high T1 signal. These sequences are acquired in the three orthogonal planes and, because of rapid acquisition, are relatively unaffected by motion-related artifacts. Examples of specific parameters for each sequence are provided in Table 1. After these three core sequences, subsequent acquisitions can and should be tailored to optimize detection of the suspected abnormalities. More recent approaches with T2-weighted imaging PROPELLER and DWI (29).

Table 1: Example of MRI protocol for anatomical assessment of the placenta

Parameter	True fast imaging with a steady-state-free-precession sequence		Single-shot fast spin-echo T2-weighted MR sequences	
Acronym	FIESTA General Electric, True FISP Siemens, BASG Hitachi, True SSFP Toshiba, Balanced FFE Philips		SSFSE General Electric, HASTE Siemens, FSE-ADA Hitachi, DIET Toshiba, UFSE Philips	
	Axial	Coronal and sagittal	Axial	Coronal and sagittal
TR/TE (ms)	3.4/1.5	3.4/1.5	2500/91.2	2500/91.2
Flip angle (°)	65	65	65	65
FOV (mm)	39	39	40	40
Matrix	224x224	224x224	512x512	512x512
Parallel imaging acceleration factor	1	1	1	1
Slice thickness (mm)	4	4	4	4
Intersection gap (mm)	1	1	1	1
Duration (minutes seconds)	1 min 03 s	41 s	1 min 35 s	1 min 30 s

TR: repetition time; TE: echo time; ms: milliseconds; FOV: field of view

Placenta accreta spectrum (PAS): the prevalence varies widely (2-90/10000 pregnancies) (30–33)

MRI provides complementary aspects to ultrasound in the diagnosis of PAS, particularly for placentas in lateral and posterior positions (34,35). PAS refers to abnormal adhesive and penetrative placental tissue in relation to the myometrium without an intervening decidua basalis. PAS is divided into accreta, increta, and percreta (Figure 5 and 6) based on degree of myometrial invasion. The incidence of placenta accreta has increased (1/2500 to 1/533) and seems to parallel the increasing rate of cesarean delivery (36,37). The main risk factors are previous uterine surgeries, advanced maternal age and placenta previa in the setting of a uterine scar. It has been reported that the risk of placenta accreta in a woman with placenta previa with one previous caesarean is around 11% and rise to 67% in cases of five or more cesarean (38). Because of high maternal morbidity, prenatal detection is important.

The management of women at risk is based on Doppler ultrasound and MRI, particularly during the third trimester of pregnancy, with similar diagnostic performance (39). Initial assessment is based on transabdominal and transvaginal ultrasound and the diagnosis is usually completed using MRI especially in those cases for which ultrasound is inconclusive, or to more precisely delineate the area and depth invaded by the placenta. MRI signs of PAS are well-described (40):

1. The disruption of tri-layered appearance of the myometrium
2. A lobulated myometrial-placental margin
3. Dark intraplacental bands
4. Abnormal placental vascularity
5. Outward bulging of the placenta with disruption of the smooth outer uterine contour
6. Direct invasion of adjacent organs

Some imaging planes can lead to a false-positive diagnosis owing to the curved shape of the uterus. Thus, suspicious findings should be confirmed in more than one imaging plane. The accuracy of these signs was evaluated in a meta-analysis (41). They identified that focal interruption of the myometrium (sensitivity, 92% (95% CI, 79.2 – 97.2%); specificity, 75.6% (95% CI, (50.4–90.4%)) and the presence of dark intra-placental bands (sensitivity, 87.9% (95% CI, 70.9 – 95.6%); specificity, 71.9% (95% CI, (55.6–84%)) on T2 weighted sequences showed the best sensitivity, while tenting of the bladder (sensitivity, 80% (95% CI, 28 – 99.5%); specificity, 98.6% (95% CI, (92.2–100%)) and uterine bulging had the best specificity to predict PAS. Evaluation of MRI interobserver agreement in PAS was excellent to predict the depth of placental invasion but was lower to assess the topography of invasion (42). This study highlights the need for a standardized MRI protocol to assess PAS.

The diagnosis of PAS is based on MRI and ultrasound findings, and patient risk factors. The first step is to look for all the MRI signs of abnormal-looking placenta described above. Then, the degree of invasion needs to be specified: accreta, increta or percreta. Differentiating a placenta percreta invading adjacent organs from a normal placenta is relatively simple. However, it is important to be alerted to the possibility of PAS when only a few of the MRI signs are seen on a limited portion of the placenta with a relatively preserved myometrium in case of placenta accreta. In our experience, their exists the potential for false positive diagnosis in particular due to the curvature of the uterus (16), and therefore we suggest that placental abnormalities be confirmed in two different planes and on two different sequences. The added value of gadolinium injection and the radiologist experience for the diagnosis of PAS has been evaluated (3,43). Both contrast injection and radiologists' experience increase the ability to diagnose PAS by MRI significantly and independently. Nevertheless, the use of contrast agents, including gadolinium, remains controversial during

pregnancy so it should be only considered in a very limited number of difficult cases where the benefits of more specific diagnosis are felt to outweigh the currently unknown risks.

Placental insufficiency

Placental exchange and oxygen saturation, remains an exciting and major area of interest though it is still poorly understood (44). As it relates to fetal growth and pregnancy outcomes, functional techniques are therefore being developed in order to gain a better understanding, and further the exploration, of this physiology, with notable example being arterial spin labelling sequences (ASL) or BOLD sequences (45). Various functional parameters can be abnormal and are discussed elsewhere in this issue. In the meantime, the general appearance of the placenta may vary, and vascular placental pathologies could be suspected by morphological analysis (46). The T2 and T2* values are lower in cases of placental insufficiency, giving the placenta a darker appearance, with greater heterogeneity, possibly due to areas of infarction and fibrosis (47). The placenta is also smaller in intrauterine growth restriction as compared to normally grown fetuses, and has a thickened globular appearance (48).

Due to the absence of adequate safety information in human fetuses, the injection of gadolinium remains controversial and is currently not recommended in routine fetal or placental MRI to explore vascularization (49).

CONCLUSION

In conclusion, a placental abnormality can be identified on MRI either incidentally or as part of the assessment of a placental abnormality. The main placental anomaly for which an MRI may be requested is PAS. MRI plays an important role in more accurately defining

prenatal placental aspects that may have serious maternal and fetal consequences. The maternal consequences of undiagnosed PAS are so serious that it is important to look for every sign that may point to the diagnosis of PAS. These signs must therefore be well known: the disruption of tri-layered appearance of the myometrium, a lobulated myometrial-placental margin, dark intraplacental bands, abnormal placental vascularity, outward bulging of the placenta with disruption of the smooth outer uterine contour, direct invasion of adjacent organs.

Thus, it is important not to overlook the placenta in an MRI examination, even when it is done for another fetal indication. Another very active field of research is the functional evaluation of the placenta. We believe in the development of new sequences to improve the prenatal diagnosis of placental insufficiency.

In summary, what the radiologist needs to know about placenta?

- The location of the placenta in relation to the cervix

- The location of the umbilical cord, which may point to vasa previa.

- Signs of myometrial invasion and appearance of PAS

- Frequent placental anomalies

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FIGURES and LEGENDS

Figure 1: Normal placenta: (A and B) sagittal planes T2 (SSFSE) at 34 weeks' gestation. The placenta appears homogenous with a plane of separation between the placenta and the uterine wall, represented by the tri-layered appearance of the myometrium. At the third trimester the placenta becomes more lobulated. The umbilical cord insertion can be identified on the chorionic plate in T2 weighted images. (C) shows a normal central insertion and (D) a velamentous insertion of the umbilical cord.

Figure 2: Low lying placenta. (A) Distance between the internal os of the cervix "C" and the end of the placenta "P" was 11 mm (red arrow). The normal myometrium on T2-

weighted imaging has a tri-layered appearance secondary to the vascularization in the middle of the myometrium and is well visualized (white arrows). Sagittal (B and D) and axial (C and D) planes in T2-weighted (SSFSE) show a bilobed placenta "P" with velamentous umbilical cord "*" adjacent to the cervix. This configuration of the placenta could suggest vasa previa.

Figure 3: Axial (A) and sagittal (B) SSFSE T2-weighted showing a thick placenta, up to 7 cm thick.

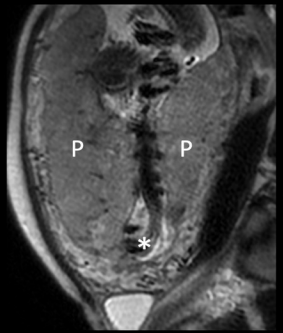
Figure 4: Large chorioangioma which measure 6 cm long axis (*). The benign tumor appears hypointense to the placenta "P" on T2-weighted images.

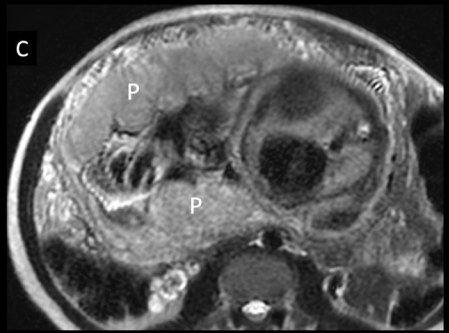
Figure 5: Images A, B, C are T2W SSFE based sequences and D sagittal plane on STIR sequence (short TI inversion recovery). (A) Sagittal plane of the placenta represents the disruption of tri-layered appearance of the myometrium and a focal uterine bulge (continuous white arrow). (A) Dotted white arrow indicated the normal tri-layered aspect of the myometrium. (B) Dark intra-placental bands are well-visualized (white arrows). Planes C and D represents abnormal placental vascularity with transfixing vessels (white arrows). The overall MRI findings are consistent with placenta accreta.

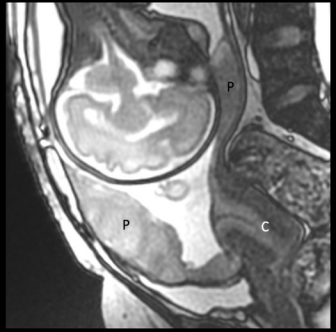
Figure 6: Placenta percreta on sagittal planes in T2-weighted SSFSE. Abnormal placental vascularity with transfixing vessels (white arrow), dark intra-placental bands, disruption of tri-layered appearance of the myometrium and bladder invasion.

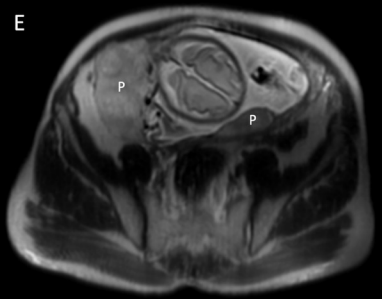

A
B
C
D

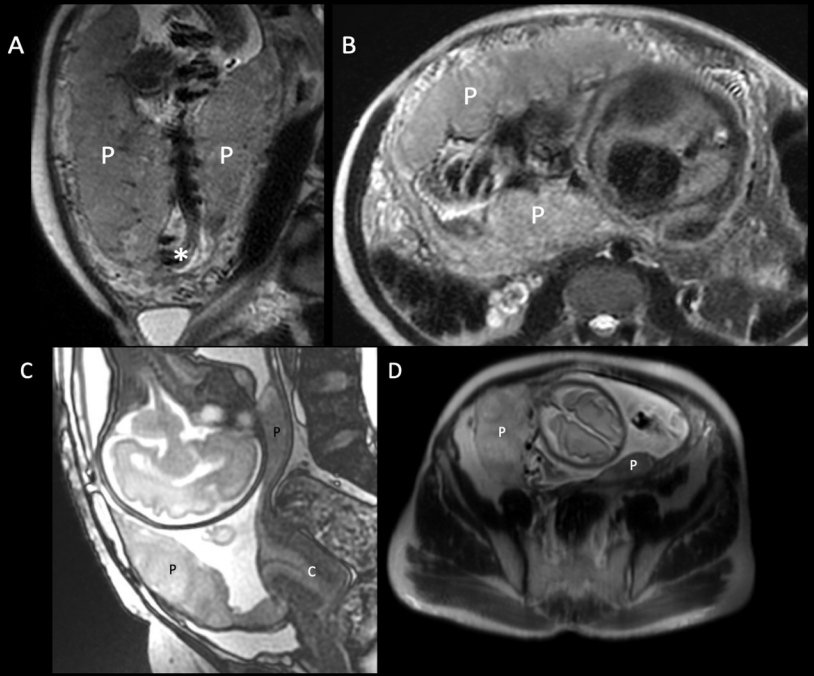

A
P
C
B

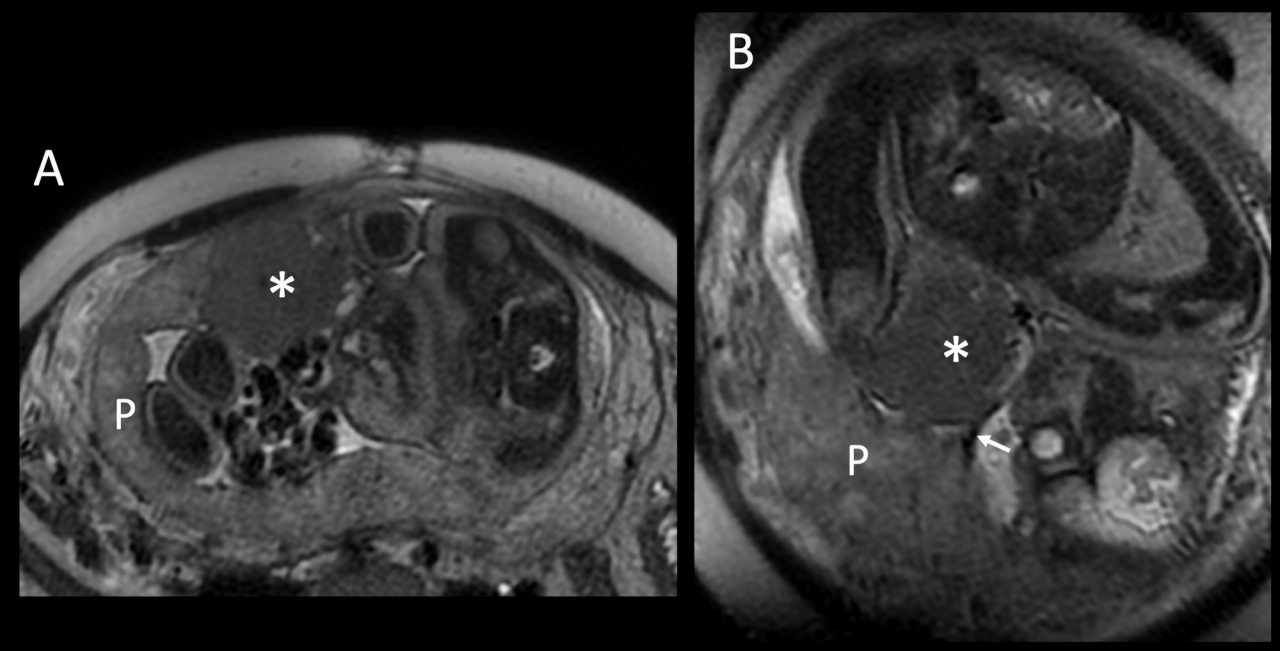

B
P
P
*

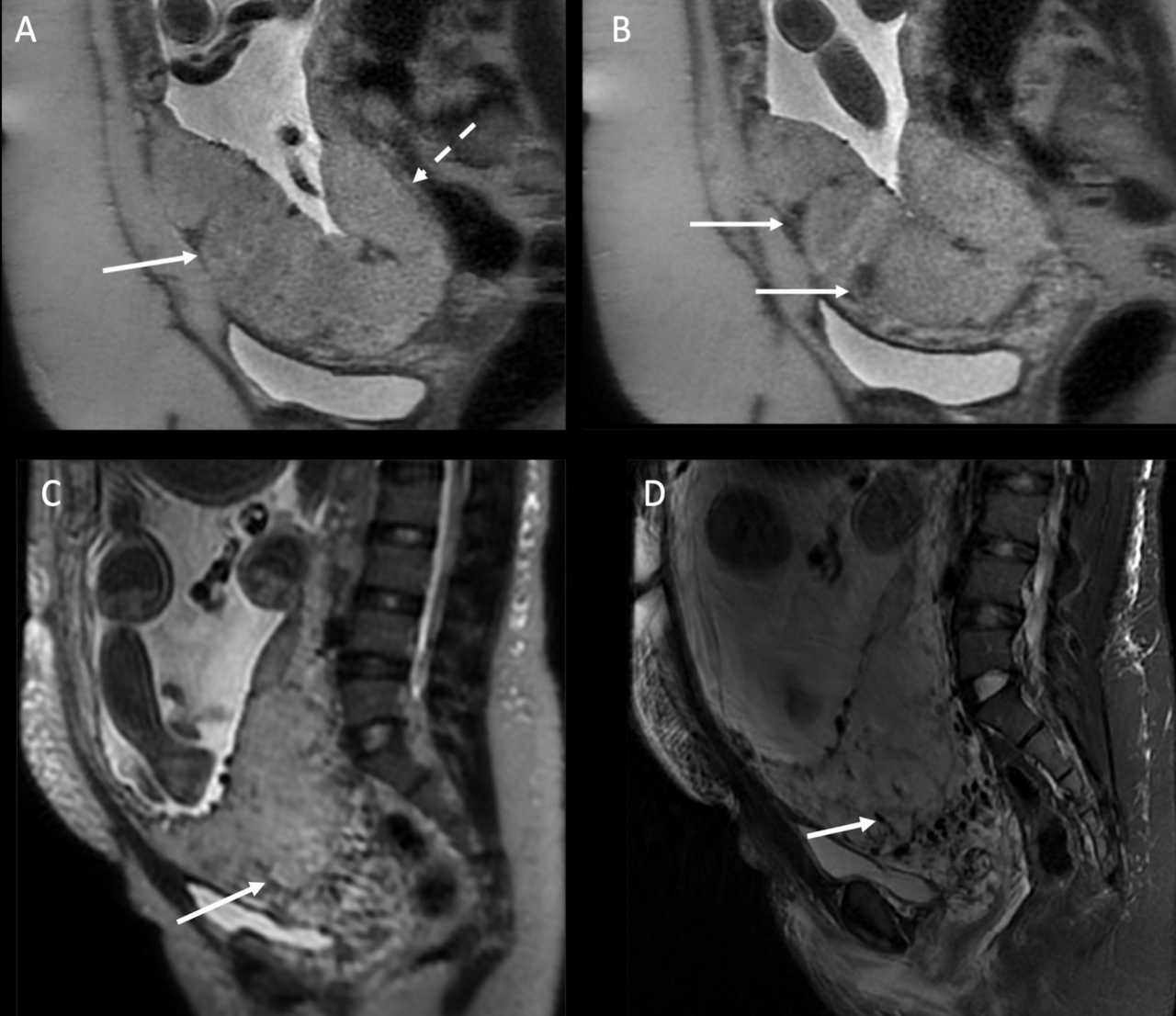

C
P
P

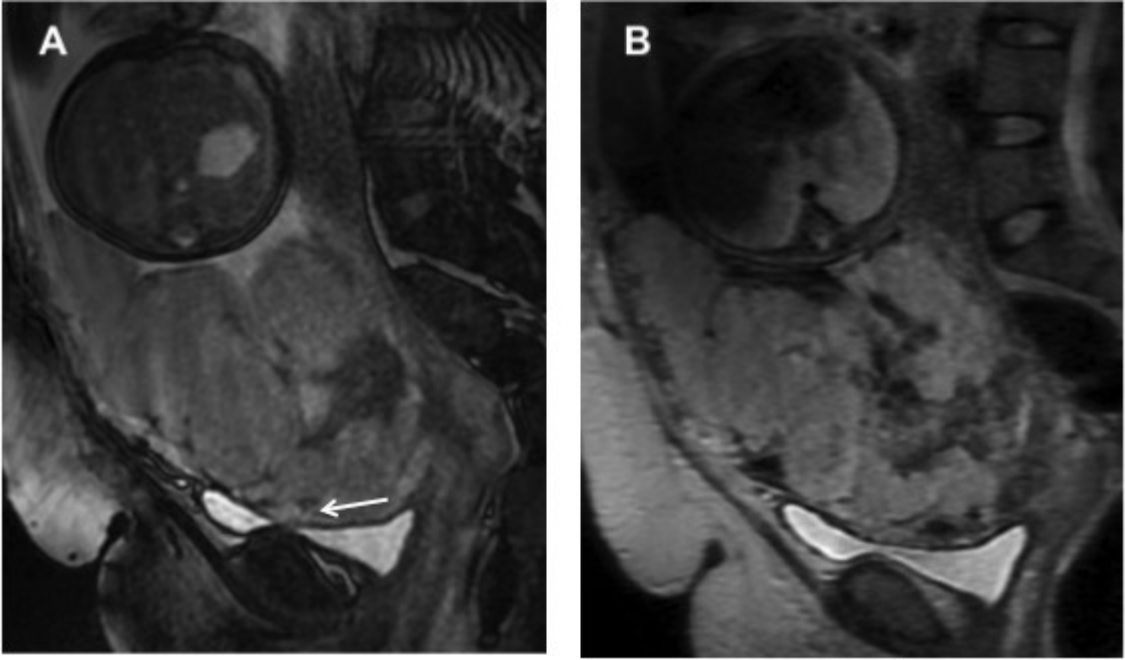

D
P
P
C


E
P
P


A
P
P
*
B
P
P
C
P
P
C
D
P
P


A
*
P
B
*
P


A
B
C
D


A
B