MRI in the diagnosis and surgical management of abnormal placentation

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Abstract

Objective. To determine the usefulness of placental magnetic resonance imaging (MRI) in the diagnosis and surgical management of abnormal placentation. Design. Retrospective follow-up. Setting. Buenos Aires, Argentina. Population. 547 pregnant women. Methods. In all cases, a direct and reliable description of abnormal placentation features was obtained by the operating surgeon. Placental MRI was analyzed according to: (1) primary description, (2) invasion topography, (3) modification required to the surgical tactics or techniques and (4) by positive and negative predictive values. Main outcome measures. Ultrasound and MRI findings were compared with surgical results, which were considered a final diagnosis in relation to primary diagnostic indications. Results. Placental MRI was obtained because of diagnostic doubt in 78 cases, for deep invasion diagnosis in 148 cases and to define the invasion area in 346 cases. Placental MRI allowed accurate demarcation and assessment of the degree of placental invasion, parametrial involvement and cervico-trigonal vascular hyperplasia, permitting changes in the surgical tactical approach. Ultrasound and MRI differences were associated with placenta previa, uterine scar thinning and use of different criteria for placental invasion through definitions or terminology. Six cases of false-negative and 11 of false-positive findings were reported. Conclusion. Placental MRI provides excellent characterization of the degree and extension of placental invasion. Its usefulness in cases of adherent placenta is directly associated to the therapeutic measures, especially where dissection maneuvers are needed. Diagnostic differences between ultrasound and MRI related to the presence or not of placenta previa and uterine scar thinning.

Abbreviations: AIP, abnormally invasive placenta; CTVH, cervical trigonal vascular hyperplasia; MRI, magnetic resonance imaging; pMRI, placental magnetic resonance imaging.

Introduction

Increasing rates of abnormally invasive placentation, such as placenta accreta, increta or percreta, are strongly associated with a rising and high proportion of deliveries being undertaken by cesarean section almost worldwide, despite efforts to reduce this trend (1). Abnormally invasive placenta (AIP) is associated with hemorrhage and with the clinical complications of this, such as hypovolemic shock, coagulopathy and multiorgan failure. Preoperative diagnosis usually allows coordination of efforts and resources to manage this complex condition in a safer way (2).

Key Message

An accurate preoperative diagnosis is one of the best methods to anticipate complications in abnormal placentation. However, the precise diagnostic are related with technical details, study preparation and the specific training of radiologist. As happened before with the ultrasound, advances in the MR diagnosis are depending of continuous feedback.
Ultrasound is an accurate method to diagnose AIP, widely available, relatively low-priced, and with high sensitivity and specificity (3). Doppler studies offer a complementary method to two-dimensional ultrasound imaging, although this has not conclusively been demonstrated to increase accuracy. However, Doppler can be used to diagnose early stages of AIP (power mode) and it is also of value in the assessment of placental involution when the placenta is left in situ after delivery.

Early in the 1990s, magnetic resonance imaging (MRI) was introduced as a diagnostic method in cases of third trimester bleeding (4). A few years after that, MRI studies were focused on the placenta following an interest in the prenatal diagnosis of AIP. Initial experiences were concentrated on assessment of whether MRI was better than ultrasonography (US). Sensitivity and specificity of both methods were similar, although an advantage of MRI was suggested with regard to resolution in cases of posterior uterine wall invasion (5). MRI was used in cases of ultrasonographic diagnostic doubt and also to classify the placental invasion degree. Then, and as a consequence of the quality definition obtained in all planes, placental MRI (pMRI) was used to evaluate the anatomy and limits of placental invasion (6). However, this knowledge was not always applied in surgical practice, probably because it is not easy to rebuild 2D diagnostic images in a 3D surgical field, or because some centers preferred to leave the placenta in situ to avoid bleeding and an expected difficult dissection. Placental spatial invasion is closely related to the specific uterine blood supply in the invasion area and linked to the possibility of complications during attempted resection procedures (7).

To clarify the specific utility of pMRI, we have analyzed its usefulness in the diagnosis and surgical treatment of AIP.

Material and methods

Between 1994 and 2011, 572 placental MRI scans were performed on women with an ultrasound diagnosis or suspicion of AIP. In 272 women the pMRI was performed with a Philips Achieva™ 1.5 T closed resonator (Philips Healthcare, Best, Netherlands) using sequences T2 single shot and T1 fast field echo. In another 252 patients, pMRI was performed with a Picker Edge™ 1.5 T closed resonator (Picker, Cleveland, OH, USA) using sequences T2 fast spin echo and T1 spin echo. Finally, in the remaining 48 patients, a 0.23 T open Picker Outlook Proview™ resonator was used (Marconi, Vantaa, Finland), with sequences T2 express and T1 spin echo. In all women with anterior or low-lying placental implantation, 750 mL of water was instilled into the bladder 45 min before the study. The MRI coil intensifier was positioned according to the placental location, i.e. using the umbilical site for the uterine body and hypogastrium for low-lying placentas. MRI slices of 5–7 mm in the three spatial planes were used. All studies were executed by trained senior doctors and compared with the surgical findings described by the operating surgeon. Surgical outcomes were considered to be definitive diagnosis according to clinical criteria for abnormal placentation. The following placental MRI parameters were analyzed: (1) primary indication, (2) invasion topography, (3) modification of the surgical tactics or techniques as a consequence of the MRI findings and (4) positive and negative predictive values for MRI and ultrasound in relation to the surgical results.

Ultrasound diagnostic findings were compared with the pMRI results according to the primary indication, as requested by the obstetrician. Placental MRI usefulness was compared with current therapeutic options for definite diagnosis of abnormal placentation, such as total and subtotal hysterectomy, conservative treatment (leaving the placenta in situ) and one-step conservative surgery. Women were recruited from a population of about 11 million inhabitants in the Buenos Aires area where the cesarean rate is currently between 30 and 70%, and live births number around 40 000 per year. All women had ultrasound suspicion or diagnosis of abnormal adhesive placentation, and all of them had recognizable risk factors. Chi-squared tests were performed to analyze differences between surgical and MRI diagnosis. A p value of < 0.05 was considered significant.

Results

The study population was divided into indication groups according to the specific pMRI pre-test indication by the obstetrician in charge. Placental MRI was requested in 78 cases because of ultrasound investigation doubts, in 148 cases the indication was the need for deep invasion diagnosis, and in 346 cases in order to delineate the invasion area. Vesical semi-repletion, a focus on the suspected area and the application of fast techniques allowed better visualization in anterior or lower placental invasion cases. Analysis of cases diagnosed by ultrasound (diagnostic doubt and invasion degree groups) showed differences in 271 cases with respect to pMRI findings. Nevertheless, in 228 of them (84.1%), the changes were associated to inadequate use of placental invasion degree terminology. Only in 43 cases (15.9%) were the diagnostic differences related to the method or the operator (p < 0.05). In 16 cases, ultrasound could not be used to make a distinction between placenta accreta and placenta previa. In these cases, ultrasound suggested only isolated signs of invasion, such as presence of abnormally profuse low blood supply to the uterus and/or myometrial thinning. With placental MRI, one false-positive result suggesting placenta accreta was made in a case of simple placenta previa. Among all patients it was possible to identify risk factors for abnormal placenta in 501 cases (87.6%), where the invasion was mainly located to the lower uterine segment or below it (S2 area). The
remaining 71 cases (12.4%) were situated in the uterine body (S1 area). In 86 cases, parametrial invasion was diagnosed by pMRI and the signs were especially evident in axial and coronal slices; this made it necessary to perform preoperative ureteral catheterization or surgical ureteral identification during the operative procedures, which also implied pelvic dissection. MRI identification of cervical trigonal vascular hyperplasia (CTVH) led to modified surgical tactics to avoid performing a total instead of a subtotal hysterectomy. Both parametrial invasion and CTVH were findings exclusively seen on pMRI.

In 559 cases (97.9%) there was accurate correspondence between pMRI invasion topography and the surgical findings. The predominantly invaded placental area prompted the use of specific proximal vascular control measures such as uterine artery catheterization and specific uterine hemostatic methods. Eleven cases of false-positive diagnoses were reported, involving two cases of placenta previa reported as placenta accreta, and nine cases of placenta percreta described as placenta accreta. Six cases of false-negative diagnosis were described (predictive positive value for MRI 98%, predictive negative value 98.9%). All were related to myometrial uterine scar disruption with secondary placental advancement into the neighboring tissues, but this was reported as placenta accreta. The usefulness of pMRI compared with ultrasound was not significantly better as a diagnostic method, except for deep placental invasion and for topographic invasion mapping, i.e. identification of a specific invaded area in the uterus (100% accuracy), parametrial involvement (96.8% accuracy); presence of CTVH (100% accuracy) and posterior AIP (100% accuracy). The utility of placental topographic information was related to surgical treatments, such as hysterectomy or conservative reconstructive procedures, which became necessary during pelvic dissection maneuvers. In these cases, extravuterine presence of placental tissue, into the bladder or the parametrium, can modify the surgical approach.

**Discussion**

Due to advances in ultrasound characterization of placental invasive disorders, placental MRI has progressively lost its primary indication as a method to resolve diagnostic doubt. Due to the reliability of ultrasound, when it is decided to leave the placenta in situ (8) no additional diagnostic invasion mapping may become necessary. But when a resection procedure such as hysterectomy or one-step conservative surgery is indicated (9), knowledge of invasion anatomy is highly recommended to perform a safe dissection (10).

Histological classification of abnormal placentation is retrospective and not useful for surgical planification. In some cases, microscopic examination revealed placenta accreta, but clinically it went unnoticed (11). Since the placenta and the pregnant uterus are a large organ, histological samples can be taken from areas with a completely different invasion degree. As multiple variables can affect an accurate diagnosis, our proposal to perform a best classification for abnormal placentation must include a surgical gross examination and a histologic study of samples taken from specific areas and from fresh tissues (gold standard).

Ultrasonography remains the diagnostic standard, but MRI can provide information on depth of invasion (12). Analysis of diagnostic doubts and invasion degree discrepancy between ultrasound and pMRI revealed that most of these differences were associated to the inadequate use of placental invasion terminology. By definition, placenta percreta invades the full thickness of the uterine wall and reaches the uterine serosa or beyond it; in some ultrasound reports this invasion degree is classified as placenta accreta.

Diagnostic doubt about AIP after ultrasound examination was especially seen in women without clinical risk factors and with no ultrasound signs or patients with clinical risk factors and absence of or minimal ultrasound signs. The presence of exuberant pericervical blood flow or myometrial thinning were the most common causes of a false-positive ultrasound diagnosis. Such signs may lead to an error when there is a low-lying placenta, especially if not associated with other ultrasound signs or clinical risk factors for abnormal placentation. Although pMRI can also fail in these cases, the total volume acquisition by multiplanar images would reduce this possibility. The presence of parallel thick vessels instead of perpendicular ones in low-lying placentas can be highly suggestive of placenta previa (10). If this sign coexists with myometrial thinning, usually in a cesarean scar, the diagnosis between these conditions may be difficult. The possibility to evaluate a suspected area through 3D planes could explain the better diagnostic performance of pMRI in these circumstances.

The reasons why some obstetricians requested a pMRI study to classify the placental invasion degree were not clear in all instances; some obstetricians prefer hysterectomy for placenta percreta (13) and others strictly conservative options (14).

Probably one of the main differences between ultrasound and pMRI is the possibility to determine the spatial

### Table 1. Determination of invasion topography (n = 342).

<table>
<thead>
<tr>
<th>Invasion</th>
<th>MRI diagnosis</th>
<th>Surgical diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 area</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>S2 area</td>
<td>311</td>
<td>311</td>
</tr>
<tr>
<td>Parametrial</td>
<td>59 (S2)</td>
<td>58 (S1)</td>
</tr>
<tr>
<td></td>
<td>4 (S1)</td>
<td>3 (S2)</td>
</tr>
<tr>
<td>CTVH</td>
<td>4 (S2)</td>
<td>5 (S2)</td>
</tr>
<tr>
<td>Posterior</td>
<td>6 (S1)</td>
<td>6 (S1)</td>
</tr>
</tbody>
</table>

S1, Sector 1: uterine body; S2, Sector 2: uterine segment-cervix; CTVH, cervico-trigonal vascular hyperplasia.

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Table 2. Placental MRI and surgically induced changes.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>S1 invasion</th>
<th>S2 invasion</th>
<th>Parametrial invasion</th>
<th>CTVH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgery</td>
<td>OSCS-SA H</td>
<td>OSCS-TAH</td>
<td>OSCS-TAH</td>
<td>OSCS-SA H</td>
</tr>
<tr>
<td>Proximal vascular control</td>
<td>Uterine or anterior iliac artery</td>
<td>Aortic or bilateral common iliac</td>
<td>Aortic or bilateral common iliac</td>
<td>Aortic or bilateral common iliac</td>
</tr>
<tr>
<td>Uterine vascular control</td>
<td>UAE-UAL-compression sutures</td>
<td>IIAE-CHO square suture</td>
<td>IIAE-CHO square and simple suture</td>
<td>Avoid dissection or embolization</td>
</tr>
<tr>
<td>Ureteral catheterization</td>
<td>Not necessary</td>
<td>Recommendable</td>
<td>Mandatory</td>
<td>Recommendable but usually very difficult</td>
</tr>
</tbody>
</table>

S1, Sector 1: uterine body; S2, Sector 2: uterine segment-cervix; CTVH, cervico-trigonal vascular hyperplasia; OSCS, one-step conservative surgery; SAH, subtotal abdominal hysterectomy; TAH, total abdominal hysterectomy; UAE, uterine arterial embolization; UAL, uterine artery ligature, IIAE, iliac internal arterial embolization.

delineation of the area invaded by the placenta (topography), which is closely related to surgical findings (Table 1). This prompts surgical measures to avoid expected complications (Table 2). Knowledge of uterine vascular areas, i.e. the lower uterus, cervix and upper vagina (S2) and uterine body (S1) (9), provides information about potential technical difficulties at operation, and allows for planning with regard to specific hemostatic methods (15) and also to avoid damage to the ureters (9).

Apart from the classification of the surgical procedures by uterine vascular area, diagnosis of parametrial invasion (Figure 1) and cervical-trigonal vascular hyperplasia (Figure 2) were findings only offered by pMRI. In general, parametrial invasion covers the ureters from the front, but in some cases, placental invasion can pass to the tissues behind the ureter (9). In these cases, the invasive placental tissues could move the ureter towards a more medial position. Ureteral invasion is usually a consequence of exuberant newly

formed vessels around it (induced by parametrial invasion) and not only of placental tissue itself (16). This type of involvement is not common at all; however, it is very difficult to deal with (17) because of the closeness to the pelvic ureter.

Although uncommon, CTVH is a potentially dangerous condition associated with some types of abnormal...
placentation. This variation cannot be diagnosed by ultrasound, and many cases even go unnoticed by pMRI. A colpouterine anastomotic system may be formed between the bladder trigon and the cervix. Since these vessels (vaginal arteries and lower vesical arteries) arise from the internal pudendal artery, endovascular hemostasis in CT VH is not possible through ligation or other closure methods of the uterine arteries or the anterior divisions of the iliac internal artery (14). In these cases, and owing to the shared irrigation between the trigonal area and the cervix, arterial embolization is not recommended because of the possibility of unwanted embolization, such as ischemia or necrosis of the trigonal bladder area. To date, we have been unable to identify publications which mention this sign. Our first identification of this pMRI sign was retrospective with regard to the surgical findings.

Although the advantage of pMRI in posterior invasion has been suggested (5), it was not possible to identify any published images of this (Figure 3). In the group of women studied here, the incidence of posterior invasion was extremely low (6/572). Ultrasound studies lead to a suspicion of three such invasion cases, while three remained undetected. Placental MRI was indicated because all the patients had an antecedent of multiple posterior myomectomies, which was related to the current placental attachment. Placental MRI detected all cases of posterior invasion, but in one of them a possible low invasion with rectal involvement was suspected. Due to the absence of a natural “contrast”, such as the full bladder in anterior invasions, the placental tissue was especially enhanced with gadolinium. Even though posterior invasion can be seen through sagittal or axial pMRI slices, axial planes provide the best visualization for diagnosis. To date, gadolinium has not shown collateral effects during pregnancy, and there are no reports of toxicity or future damage to the fetus (18,19). However, the use of gadolinium is generally recommended for those cases not evident through other methods and they still carry a theoretical possibility of fetal or maternal risk.
Diagnostic differences between ultrasound and pMRI may be the consequence of multiple factors, such as deficient or excessive bladder filling, insufficient bladder or uterine pressure, operator experience, equipment and patient conditions (scars, obesity, myomas), among others. There was a slight difference between ultrasound and pMRI. However, pMRI is more reliable for diagnosing the degree of placental invasion (20) and for showing the topography of the invaded area. The current tendency is to use pMRI to estimate the extension and the spatial relation of the invaded tissues, in order to use conservative or resective treatments (Figure 4) (7–22). The possibility to examine a total volume of invasion in multiple slices and spatial positions could be the cause of this difference between the two diagnostic methods.

Conclusions
Placental MRI has an auxiliary role as a diagnostic method in abnormal placentation, and it is especially useful for a differential diagnosis in cases of placenta previa or uterine scar thinning. pMRI appears to be more reliable as a method than ultrasound to characterize different types of invasion degree, although its presurgical application is not clear. Nevertheless, pMRI is probably the most accurate method to establish a topographic extension of the invaded area, which has a consistent relation with the specific blood supply and among the pelvic structures. This precise information has a direct application in resective procedures such as hysterectomies or one-step conservative surgery.

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References

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