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# Application of Indirect Signs of Magnetic Resonance Imaging (MRI) in Prenatal Diagnosis of Abnormally Invasive Placenta

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

ABCD Fang Huang*
EFG Qing-quan Lai*
CDE Hong Wu*
BDE Xiao-ting Ke

Department of Radiology, The Second Affiliated Hospital, Fujian Medical University, Quanzhou, Fujian, P.R. China

* Fang Huang, Qing-quan Lai and Hong Wu contributed equally to this study and share the first authorship

**Corresponding Author:** Fang Huang, e-mail: huangfang8012@163.com
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**Background:** The aim of this study was to assess the value of indirect MRI signs in the prenatal diagnosis of abnormally invasive placenta (AIP).

**Material/Methods:** This study involved the retrospective analysis of indirect signs of 109 patients with AIP and 59 patients without AIP. The numbers of cases of placenta increta, accreta, and percreta confirmed by surgical and pathological results were 54, 19, and 36, respectively. The indirect signs included the following: dark intraplacental bands in T2WI sequence, focal outward bulging of the placenta, abnormal placental vascularity, and heterogeneous placental signal intensity.

**Results:** There were significant differences in dark intraplacental bands in T2WI sequence, focal outward bulging of the placenta, and abnormal placental vascularity between the AIP and the non-AIP groups. There was no significant difference in dark intraplacental bands in T2WI sequence between the placenta percreta and increta groups, but there was a significant difference between the other 2 AIP groups and the placenta accreta group. Focal outward bulging of the placenta was significantly different between the percreta group and the placenta accreta group, but there was no significant difference between the other 2 AIP groups and the placenta increta group. There were no significant differences in abnormal placental vascularity among the3 subtypes of AIP.

**Conclusions:** The indirect signs of dark intraplacental bands in T2WI sequence, focal outward bulging of the placenta, and abnormal placental vascularity are reliable signs of AIP. The indirect sign of dark intraplacental bands in T2WI sequence may be used to distinguish placental accreta from the other 2 subtypes of AIP.

**MeSH Keywords:** Magnetic Resonance Imaging • Placenta • Placenta Diseases

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## Background

Abnormally invasive placenta (AIP) is caused by direct contact between the myometrium and the chorionic villi due to defects of the normal decidua basalis [1]. The strongest risk factors for AIP are as follows: placenta previa, prior caesarean section, advanced maternal, and multiple abortions [2–4]. The cesarean delivery rate in the United States rose from 4.5% in 1965 to 32.9% in 2009, and the rate of abnormal placentation also increased from 1/2500 to 1/500 [5]. Postpartum hemorrhage is an important cause of AIP, and it is also one of the main causes of maternal death [6]. Accurate and timely preoperative diagnosis can help the obstetrician to make a surgical plan to reduce the incidence of fetal and maternal morbidity, including severe hemorrhage, perinatal hysterectomy, and other adverse perioperative events [7]. The diagnosis of AIP can be confirmed by obstetric ultrasound and prenatal magnetic resonance imaging (MRI). MRI has the obvious advantage of providing a larger field of view and greater soft tissue contrast and can better show the topography and extension of AIP. Therefore, the application of MRI is becoming increasingly extensive, especially in the case of uncertain ultrasonic diagnosis.

Direct signs, including loss of the dark retroplacental zone and indistinct or thinning myometrium, have been used as common criteria for the MRI diagnosis of AIP. Recently, several papers described some indirect signs, such as abnormal uterine bulge, intraplacental dark T2 bands, and heterogeneous placental signals, as being useful in diagnosis [8,9]. However, there are no uniform MRI diagnostic criteria for AIP, and the value of MRI indirect signs for the diagnosis and the differential diagnosis of each subtype of AIP remains unknown. The aim of this study was to analyze MRI indirect signs in patients with AIP and to investigate their value in diagnosis.

## Material and Methods

We retrospectively analyzed data on 109 patients who underwent prenatal MRI at a regional referral center for AIP between October 2015 and December 2018. The diagnosis of AIP was confirmed following a caesarean section and subsequent pathological examination from the Department of Obstetrics. MRI was conducted 1 week before the caesarean section, and the image quality could be used for diagnosis. Clinical data were collected. During the same period, 59 patients without AIP confirmed by natural labor or cesarean section were enrolled in the control group; they were suspected to have placenta previa by ultrasound or ultrasonic-fetal dysplasia in late pregnancy. Among 109 patients, there were 54 cases of placenta increta, 19 cases of placenta accreta, and 36 cases of placenta percreta, confirmed by surgical and pathological results.

A Philips Achieva Nova Dual MR 1.5 T scanner or GE Hdxt1.5 T scanner and body coils were used for scanning. The scan ranged from approximately 2 cm above the uterus to the pubic joint. Coronal, sagittal, and axial planes were taken in single-shot fast spin-echo, turbo spin-echo (ssFSE, ssTSE), and balanced steady-state free precession modes (BTFE or FIESTA). Coronal and sagittal fat-suppressed gradient echo T1-weighted images were used to assess blood products. Sagittal diffusion-weighted imaging (DWI) was also used. The SSTSE sequence parameters were as follows: TR 7500 ms, TE 100 ms, 1 signal acquisition, reverse angle 90°, layer thickness 5 mm, Matrix 256×256, and scanning time of 12–16 s. The FIESTA parameters were as follows: TR 3.60 MS, TE 1.78 MS, 1 signal acquisition, reverse angle 90°, layer thickness 8 mm, Matrix 256×56, and scanning time of 14–18 s. T1WI used a fast spin wave sequence under the screen, TR 832 ms, TE 14 ms, 2 acquisition signals, Matrix 256×256, layer thickness 5 mm, and scanning time of approximately 2 min 30 s. Sagittal diffusion (DWI) used TR 3920 ms, TE 65.3 ms, Matrix 256×256, b=0 and b=800, layer thickness 6 mm, and scanning time of approximately 2 min 10 s.

Two independent radiologists with more than 10 years of experience in interpreting obstetrical MRI were blinded to the clinical data and obstetric ultrasound results. For each case of MRI image, the indirect signs of AIP were recorded in a spreadsheet application (Microsoft Excel; Microsoft Corporation, Redmond, WA, USA), which included: dark intraplacental bands in T2WI sequence, abnormal placental vascularity (disorganized vessels, hypertrophied or lacunae), focal outward bulging of the placenta, and heterogeneous placental signal intensity (Figure 1).

SPSS version 22.0 (SPSS, Chicago, IL, USA) was used for statistical analyses. To analyze the patients' demographic and obstetric characteristics, we used the independent-samples *t* test for continuous normally distributed data, the Mann-Whitney U test for non-normally distributed data, and the chi-square test for categorical data. The chi-square test was used to analyze the significance of differences between the AIP group and the control group. For the significantly different indirect signs, Fisher's exact test was used for each type of AIP group. $P<0.05$ was considered statistically significant. The sensitivity and specificity of MRI examination were calculated.

## Results

There were 109 patients with AIP and 59 patients without AIP in this study. We found no differences in the mean gestational age, number of pregnancies, or number of multiple pregnancies between the AIP group and control group. The number of prior cesarean section, one or either none, were significantly different between the 2 groups (Table 1). The proportion of patients with no prior cesarean section was lower in the AIP





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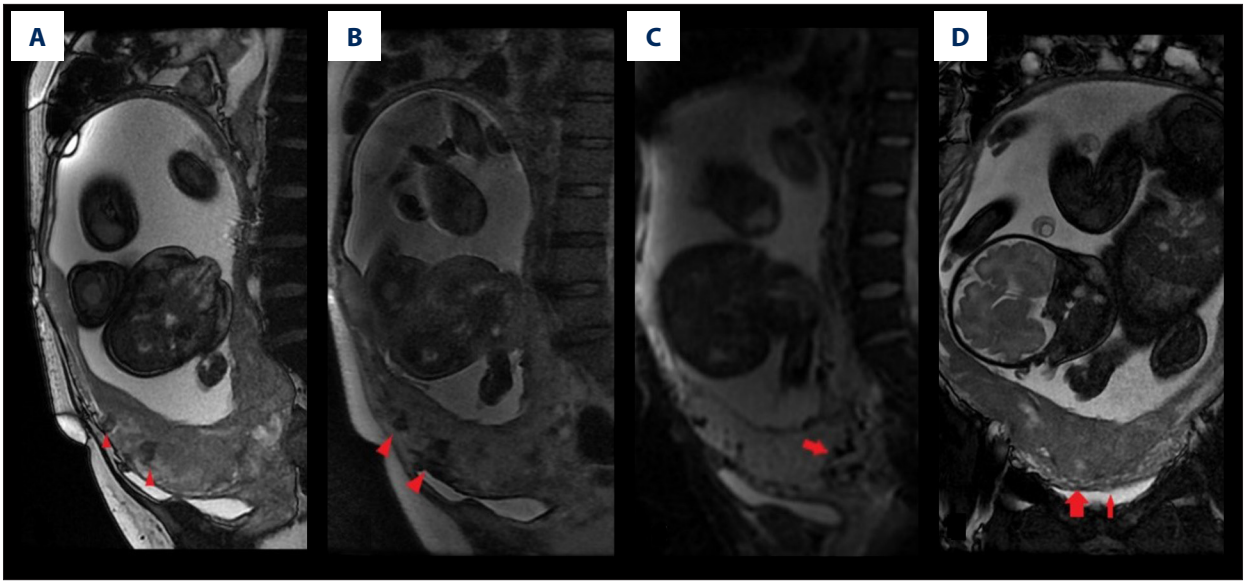


**Figure 1.** 35 years old woman, placenta percreta, 3 days before cesarean delivery. (**A**) FIESTA, OSAG, dark intraplacental bands in T2WI sequence (red arrowheads). (**B**) ss_FSE, OSAG, dark intraplacental bands in T2WI sequence(red arrowheads). (**C**) DWI (b=0), abnormal placental vascularity (red arrow). (**D**) FIESTA, OCOR, located outward bulging of the placenta (red thick arrow), disruption uterine of the serosal/bladder interface (red thin arrow)

**Table 1.** Patients' demographic and obstetric characteristics.

| Characteristic | AIP | Control group | P-value |
|---|---|---|---|
| Case number | 109 | 59 | |
| Maternal age (week) | 38.2±6.2 | 36.4±5.4 | >0.05 |
| Number of pregnancies | 2 (0–6) | 2 (0–5) | >0.05 |
| Prior cesarean sections | | | |
| 0 | 26 (23.85%) | 35 (59.32%) | <0.01 |
| 1 | 69 (63.30%) | 19 (32.20%) | <0.01 |
| 2 | 10 (9.17%) | 3 (5.08%) | >0.05 |
| ≥3 | 4 (3.67%) | 2 (3.39) | >0.05 |
| Multiple gestation | 2 | 1 | >0.05 |
| Placenta previa | 98 | 19 | <0.01 |

group than in the control group (23.85% *vs.* 59.32%, respectively). The proportion of patients with 1 prior cesarean section was larger in the AIP group than in the control group (63.30% *vs.* 32.20%, respectively). There were more cases of placenta previa in the AIP group than in the control group (98 cases *vs.* 19 cases), with a significant difference (Table 1). There were also significant differences in the indirect signs of dark intraplacental bands in T2WI sequence, focal outward bulging of the placenta, and abnormal placental vascularity between the 2 groups. There was no significant difference in the indirect signs of different placental signal intensity between the 2 groups (Table 2). For the indirect sign of dark intraplacental bands in T2WI sequence, we found a significant difference between the placenta accreta group and placenta increta group (6 cases *vs.* 47 cases, respectively) and between the placenta accreta group and placenta percreta group (6 cases *vs.* 35 cases, respectively), but there was no significant difference between the placenta increta group and placenta percreta group (Table 3). For the indirect sign of focal outward bulging of the placenta, we found a significant difference between the placenta accreta group and the placenta percreta group (8 cases *vs.* 30 cases, respectively), but there was no significant difference between the placenta accreta group and the other 2 sub AIP groups (Table 4). For the indirect sign of abnormal placental vascularity, there were no significant differences among the 3 AIP subgroups (Table 5). The sensitivity and specificity were





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**Table 2.** The outcome of chi square test analysis of MRI indirect signs between the AIP group and control group.

| MRI indirect sign | AIP group (109) | Control group (60) | Asymp Sig. (2-sided) | P-value |
|---|---|---|---|---|
| Dark intraplacental bands in T2WI sequence | 88 | 5 | 0.000 | <0.01 |
| Focal outward bulging of the placenta | 75 | 5 | 0.000 | <0.01 |
| Abnormal placental vascularity | 34 | 5 | 0.001 | <0.05 |
| Heterogeneous intraplacental signal intensity | 79 | 49 | 0.125 | >0.05 |

**Table 3.** The outcome of Fisher's exact test analysis of MRI indirect signs between the each types of placenta implantation group.

| Item | Dark intraplacental bands in T2WI sequence | Exact Sig. (2-sided) | P value |
|---|---|---|---|
| Accreta | 6 | 0.000 | <0.01 |
| Increta | 47 | | |
| Accreta | 6 | 0.000 | <0.01 |
| Percreta | 35 | | |
| Increta | 47 | 0.138 | >0.05 |
| Percreta | 35 | | |

**Table 4.** The outcome of Fisher's exact test analysis of MRI indirect signs between the each types of placenta implantation group.

| Item | Focal outward bulging of the placenta | Exact Sig. (2-sided) | P value |
|---|---|---|---|
| Accreta | 8 | 0.100 | >0.05 |
| Increta | 36 | | |
| Accreta | 8 | 0.005 | <0.01 |
| Percreta | 30 | | |
| Increta | 36 | 0.093 | >0.05 |
| Percreta | 30 | | |

80.73% and 91.53% for dark intraplacental bands in T2WI sequence, 67.89% and 91.52% for focal outward bulging of the placenta, 31.19% and 91.53% for abnormal placental vascularity, and 72.48% and 16.95% for heterogeneous intraplacental signal intensity, respectively (Table 6).

**Table 5.** The outcome of Fisher's exact test analysis of MRI indirect signs between the each types of placenta implantation group.

| Item | Abnormal placental vascularity | Exact Sig. (2-sided) | P value |
|---|---|---|---|
| Accreta | 5 | 1.000 | >0.05 |
| Increta | 16 | | |
| Accreta | 5 | 0.554 | >0.05 |
| Percreta | 13 | | |
| Increta | 16 | 0.646 | >0.05 |
| Percreta | 13 | | |

**Table 6.** The sensitivity and specificity of indirect signs.

| | Sensitivity (%) | Specificity (%) |
|---|---|---|
| Dark intraplacental bands in T2WI sequence | 80.73 | 91.53 |
| Focal outward bulging of the placenta | 67.89 | 91.52 |
| Abnormal placental vascularity | 31.19 | 91.53 |
| Heterogeneous intraplacental signal intensity | 72.48 | 16.95 |

## Discussion

AIP can often cause massive bleeding during labor. For obstetricians, accurate and timely prenatal diagnosis of AIP is important because it is the most common reason for emergency hysterectomy, postpartum hemorrhage, and maternal death [10,11]. Prenatal diagnosis might permit the planning of clinical treatment measures, which can reduce maternal mortality and morbidity [7]. MRI can correctly diagnose AIP and the depth of AIP, which can directly guide clinical diagnosis and treatment [12]. According to the degree of invasion,





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placenta increta, placenta accreta, and placenta percreta are classified as follows: placenta accreta means myometrial invasion, placenta increta means deep myometrial invasion, and placenta percreta involves invasion through the serosal layer of the uterus, with potentially more widespread invasion of adjacent organs. Lax and colleagues found 7 features with adequate interobserver variability, including direct signs and indirect signs [8].

The direct MRI signs of AIP include loss of the dark T2 interface between the myometrium and the placenta, focal interruptions in the myometrial wall, disruption of the uterine bladder/serosal interface, and more widespread invasion of adjacent organs. Previous research indicated that loss of the dark T2 interface between the myometrium and the placenta can also be observed in normal placenta [13]. Other direct MRI signs, such as focal interruptions in the myometrial wall, disruption of the uterine bladder/serosal interface, and direct widespread invasion of adjacent organs, can also be used as diagnostic criteria for AIP, but the probability of all these signs occurring at the same time is very low. Thus, we need to combine indirect signs to increase the accuracy of the MRI diagnosis of AIP [14].

The indirect MRI signs of AIP include dark intraplacental bands in T2WI sequence, focal outward bulging of the placenta, abnormal placental vascularity, and heterogeneous placental signal intensity. These dark intraplacental bands originate from the basilar plate of the maternal placenta. On BTFE/FIESTA images, the placental tissue signal was decreased, and the vascular signal was increased [8]. The cause of the formation of dark bands in the placenta is unknown, but it may be due to abnormal fibrous bands or sequelae of hemorrhage [15]. Large amounts of fibrin are seen histologically in AIP patients. Derman et al. believed that abnormal placental vascularity was due to the excessive proliferation of placental tissues in the process of growth to the deep myometrium of the uterus, leading to the tortuous expansion of local vessels [9]. The abnormally tense myometrium and the mass effect of the placenta from the myometrium may cause the focal outward bulging. Hemorrhage products and artifacts from blood flow may also cause the heterogeneous placental signal intensity.

We found that focal outward bulging of the placenta, dark intraplacental bands in T2WI sequence, and abnormal placental vascularity were significantly different between the control group and the AIP group. Furthermore, we found that dark intraplacental bands in T2WI sequence were important for diagnosis, with the highest display rate. The feature had a sensitivity of 80.73% and specificity of 91.53%, which was close to the sensitivity of 87.9% and specificity of 71.9% shown in Antonio's article [16]. In the present study, abnormal placental vascularity also had high specificity (91.53%) but low sensitivity (31.19%), which is different from some other studies showing that abnormal placental vascularity signs had good sensitivity and specificity [16]. In the present study, focal outward bulging of the placenta had high specificity (91.52%) and low sensitivity (67.89%). Our funding is consistent with the research of Leyendecker, which showed a sensitivity and specificity of 79.1% and 90.2%, respectively [17]. The dark intraplacental bands in T2WI sequence, focal outward bulging of the placenta, and abnormal placental vascularity were significantly different in the 2 groups and had high specificity for AIP. Therefore, these 3 signs can be used as reliable signs for the diagnosis of AIP. We found that heterogenous intraplacental signal intensity had low specificity (16.95%) and sensitivity (72.48%), which is in agreement with the data of Bour and colleagues [18] but is different from the conclusion of Lax et al., who believed that heterogenous intraplacental signal intensity is an necessary sign for the diagnosis of AIP [8]. The low specificity may be because it is a subjective marker relying on the gestational age of the placenta, and there are no clear image parameter definitions. Indeed, this sign can be observed in 25% of normal placentas [17]. We did not find a significant difference between the AIP group and control group in our study, perhaps because these 2 groups of pregnant women were all in the late stage of pregnancy, and normal placenta with high maturity will have placenta calcification and degeneration changes.

There are different treatments for various types of AIP. Placental accreta mostly uses a conservative treatment, while clinical hysterectomy or partial hysterectomy is often required for placental increta and placental percreta. Levin et al. found that supracervical hysterectomy should be considered the first choice for patients with AIP requiring surgical management [19]. Therefore, accurate classification of AIP is conducive to aiding the clinical formulation of effective treatment measures to minimize the harm to mothers and fetuses. In this study, the valuable indirect signs were tested by Fisher's exact test in 3 types of AIP. The results showed there was no significant difference between placenta percreta and placenta increta in dark intraplacental bands in T2WI sequence, but this sign was significantly different between placenta accreta and increta and between placenta accreta and percreta. The indirect sign of focal outward bulging of the placenta was different between placenta accreta and percreta but was not different between placenta increta and accreta or between percreta and placenta increta. The indirect sign of abnormal placental vascularity was not significantly different in the 3 types of AIP. This study suggests that the indirect sign of dark intraplacental bands in T2WI sequence may be helpful in differentiating placental accreta from the other 2 diagnoses, but it is not helpful in distinguishing placenta increta and percreta; the other indirect signs may have little value in the classification diagnosis of AIP. This finding is in disagreement with other researchers, who believe that abnormal placental vascularity can provide





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meaningful diagnostic value. Derman et al. found that intraplacental T2 dark bands and abnormal placental vascularity were the most sensitive MR criteria for the diagnosis of AIP [9]. Charis Bourgioti et al. found that MRI was highly accurate in diagnosing placental percreta, with abnormal vasculature between the uterus and bladder being the most reliable sign of bladder invasion by AIP [20]. However, Gabriel Levin disagreed; he thought it was unclear if MR imaging improved the diagnosis placenta accreta spectrum beyond what can be achieved by experienced ultrasound operators [21].

The limitations of our study are as follows. The reasons for placenta implantation are complex; thus, it is necessary to expand the sample size and carry out multivariate statistical analyses in the future. This study lacked research on direct signs. Indirect signs combined with direct signs may be helpful for placental implantation classification, and direct and indirect signs should therefore be combined in the future.

## Conclusions

The indirect signs of dark intraplacental bands in T2WI sequence, focal outward bulging of the placenta, and abnormal placental vascularity were found to be reliable signs of AIP. The indirect signs of dark intraplacental bands in T2WI sequence may be helpful in differentiating placental accreta from the other 2 diagnoses, but it is not helpful in distinguishing between placenta increta and percreta.

### Conflict of interests

None.

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