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# Advanced MRI Mapping Using Diffusion-Weighted and T2 HASTE Sequences in Placenta Accreta Spectrum Disorders: Histopathological and Surgical Correlation Analysis

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**ABSTRACT**: ***Background:*** Placenta accreta spectrum (PAS) disorders are life-threatening conditions characterized by abnormal placental attachment. Early diagnosis is essential for effective surgical management. ***Objective:*** To evaluate the utility of advanced MRI mapping using diffusion-weighted (DWI) and T2 HASTE sequences for the diagnosis of PAS disorders and correlate these findings with histopathological and surgical outcomes. ***Methods:*** This study was conducted at the Department of Obstetrics and Gynecology, University of Texas Southwestern Medical Center, between January 2020 and June 2022. A total of 194 patients with suspected PAS disorders underwent MRI using DWI and T2 HASTE sequences. Histopathological confirmation was obtained post-delivery. Data analysis included the calculation of sensitivity, specificity, and p-values to assess the diagnostic accuracy of MRI in detecting placental invasion. Statistical analysis was performed using SPSS version 26.0, and the results were evaluated using standard deviation and p-value metrics. ***Results:*** Of the 194 patients, 152 (78.4%) were diagnosed with PAS disorders. The sensitivity of DWI for detecting placental invasion was 88%, while T2 HASTE demonstrated 85% sensitivity. The specificity was 92% for DWI and 90% for T2 HASTE. The correlation between MRI findings and histopathology was highly significant ($p < 0.001$). The mean standard deviation for DWI and T2 HASTE imaging was 5.5 and 6.2, respectively. Surgical outcomes indicated that 30% of patients required hysterectomy, with significant p-values (<0.05) correlating the depth of placental invasion and the need for surgical intervention. ***Conclusion:*** Advanced MRI mapping with DWI and T2 HASTE sequences offers high diagnostic accuracy and is a valuable tool in the management of PAS disorders.

**Keywords:** Placenta Accreta, Diffusion-Weighted Imaging, T2 HASTE, MRI, Histopathology.



## INTRODUCTION

The placenta accreta spectrum (PAS) disorders, encompassing placenta accreta, increta, and percreta, represent a spectrum of conditions characterized by abnormal placental attachment to the uterine wall, which can result in severe maternal morbidity and mortality. The prevalence of PAS disorders has notably increased in recent decades, attributed to factors such as increased cesarean section rates, advanced maternal age, and previous uterine surgeries, including myomectomies and curettage procedures. The condition is diagnosed when the placenta invades into the myometrium or beyond, which may complicate pregnancy and delivery, often necessitating extensive surgical intervention such as hysterectomy. While early detection is crucial for improving clinical outcomes, diagnosis remains challenging due to the insidious nature of the disease and its variable clinical presentation [1]. Recent advancements

in imaging technologies, particularly magnetic resonance imaging (MRI), have emerged as promising tools for the non-invasive evaluation of PAS disorders. MRI provides superior soft tissue contrast and can detect subtle abnormalities in placental attachment, making it invaluable for assessing the extent of invasion into the uterine wall and surrounding structures. Among the various MRI sequences, diffusion-weighted imaging (DWI) and T2-weighted half-Fourier acquisition single-shot turbo spin echo (T2 HASTE) sequences have shown substantial potential in mapping the pathological features of PAS disorders. These imaging techniques are gaining recognition for their ability to accurately visualize the altered tissue architecture of the placenta and surrounding tissues, thereby offering critical information for preoperative planning and surgical risk assessment [2].

Diffusion-weighted imaging (DWI) utilizes the diffusion of water molecules within tissues to generate high-contrast images, providing detailed insights into tissue microstructure. In PAS disorders, abnormal placental attachment often disrupts the normal tissue architecture, leading to changes in water molecule diffusion. This is particularly evident in areas of the placenta that invade the myometrium or beyond, where the increased cell density and altered extracellular matrix create distinct diffusion characteristics that can be detected using DWI. Previous studies have highlighted the utility of DWI in identifying the depth and extent of placental invasion, demonstrating its potential as a diagnostic adjunct to ultrasound and conventional MRI [3]. The application of DWI in PAS disorders is based on the premise that malignantly invasive trophoblastic cells exhibit altered diffusion properties compared to normal trophoblasts. The higher cellularity and reduced extracellular space in areas of invasion cause water molecules to diffuse more slowly, leading to hyperintense signals on DWI. This can be particularly useful in distinguishing between the different types of PAS disorders, as well as identifying the presence of placenta percreta, where the placenta invades through the uterine wall and potentially into adjacent organs such as the bladder or bowel. Moreover, DWI has been shown to provide complementary information to other MRI sequences, such as T2-weighted imaging, by enhancing the detection of placental abnormalities that may be less visible on conventional MRI scans.

T2-weighted HASTE sequences, which use a half-Fourier acquisition method, provide high-resolution images with excellent tissue contrast, particularly in the depiction of soft tissues such as the placenta and myometrium. The use of T2 HASTE in PAS disorders allows for the clear delineation of abnormal placental attachment sites and the extent of placental invasion into the uterine wall. One of the main advantages of T2 HASTE over traditional T2-weighted imaging is its ability to generate images with fewer motion artifacts, which is particularly beneficial in the evaluation of pregnant patients, where fetal motion or maternal breathing can lead to degraded image quality [4]. The T2 HASTE sequence has been shown to be particularly effective in visualizing the myometrial layer, which is critical in the assessment of PAS disorders. In cases of placenta accreta and increta, the normal interface between the placenta and myometrium becomes disrupted, and T2 HASTE imaging helps to identify areas where the placental tissue invades the myometrium. The sequence is also beneficial in detecting areas of necrosis or hemorrhage within the placenta, which can be indicative of more advanced disease stages [2]. Furthermore, T2 HASTE has been proven to complement DWI by providing additional anatomical detail that can improve the accuracy of PAS diagnosis, offering a comprehensive view of both the structural and functional changes associated with placental invasion.

While MRI provides detailed in vivo imaging of PAS disorders, histopathological examination remains the gold standard for confirming the diagnosis. Histopathological analysis of PAS disorders typically reveals varying degrees of trophoblastic invasion into the myometrium or beyond, with characteristic findings including the absence of the normal decidual layer, increased trophoblast proliferation, and trophoblastic infiltration of blood vessels. These pathological features are directly correlated with the severity of clinical symptoms, such as bleeding, and can inform surgical decision-making, particularly in terms of the need for hysterectomy [1]. Surgical management of PAS disorders is often determined based on preoperative imaging findings, including MRI. In cases of suspected placenta percreta, where there is significant invasion beyond the uterus, preoperative MRI plays a critical role in identifying potential complications, such as bladder involvement, and in guiding surgical approaches. The integration of MRI findings, such as those obtained from DWI and T2 HASTE

sequences, with histopathological results offers a more comprehensive understanding of the disease process. This correlation can improve the accuracy of preoperative planning, help predict surgical outcomes, and ultimately reduce maternal morbidity and mortality associated with PAS disorders [2].

### Aims and Objective

The aim of this study is to assess the diagnostic accuracy of advanced MRI mapping, using diffusion-weighted imaging (DWI) and T2 HASTE sequences, in detecting placenta accreta spectrum (PAS) disorders. The objective is to correlate MRI findings with histopathological and surgical outcomes, thereby improving preoperative planning and maternal health management.

## MATERIAL AND METHODS

### Study Design

This prospective observational study was conducted at the Department of Obstetrics and Gynecology, University of Texas Southwestern Medical Center, from January 2020 to June 2022. The aim of the study was to evaluate the effectiveness of advanced MRI mapping using diffusion-weighted imaging (DWI) and T2 HASTE sequences in diagnosing placenta accreta spectrum (PAS) disorders. A total of 194 pregnant women with suspected PAS disorders were included, and their clinical outcomes were correlated with MRI findings and histopathological confirmation post-delivery.

### Inclusion Criteria

Patients with a clinical suspicion of PAS disorders, such as previous cesarean sections, uterine surgeries, or advanced maternal age, were included in the study. Participants must have had a gestational age of 24 weeks or more at the time of MRI, and no contraindications to MRI, such as metal implants, were allowed. All participants provided informed consent to participate in the study.

### Exclusion Criteria

Patients with known contraindications to MRI, including severe claustrophobia, metal implants, or pacemakers, were excluded. Women with multiple gestations or severe fetal abnormalities were not included in the study. Additionally, those who were not willing to participate or unable to comply with study procedures, such as missing scheduled MRI scans or follow-up, were also excluded from the analysis.

### Data Collection

Data were collected prospectively from the enrolled patients, who underwent MRI scans using DWI and T2 HASTE sequences during their hospital stay. All scans were conducted on a 3T MRI machine, and imaging was reviewed by radiologists specializing in obstetric imaging. Histopathological samples were obtained after delivery, and surgical outcomes, including the need for hysterectomy, were documented. Demographic data, clinical histories, and MRI results were all recorded in a secure database.

### Data Analysis

Data analysis was conducted using SPSS version 26.0. Descriptive statistics were used to calculate the mean, standard deviation, and percentage distribution of variables. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of the MRI sequences were calculated. A chi-square test was used to assess the correlation between MRI findings and histopathological outcomes. Statistical significance was set at $p < 0.05$.

### Procedure

Upon enrollment, patients underwent detailed clinical evaluation, including a history of prior uterine surgeries and cesarean deliveries, along with a physical examination to assess for clinical signs of PAS. MRI scans were scheduled for each participant to evaluate placental attachment using DWI and T2 HASTE sequences. The scans were reviewed by trained radiologists to assess for signs of placental invasion into the myometrium and adjacent organs. The primary focus was on identifying the depth and extent of placental invasion, which was compared with the post-delivery histopathological examination. Histopathological results were obtained from placental tissue biopsies and examined for trophoblastic invasion. Surgical outcomes, including the need for hysterectomy, were recorded and compared to the MRI findings. The correlation between MRI diagnostic accuracy and histopathological results was then analyzed to determine the reliability and clinical utility of MRI in managing PAS disorders.

**Ethical Considerations**

The study was approved by the Institutional Review Board (IRB) at the University of Texas Southwestern Medical Center. Informed consent was obtained from all participants, who were informed of the purpose of the study, potential risks, and benefits. Patient confidentiality was maintained throughout the study, and all personal data were anonymized. The study adhered to ethical guidelines for medical research involving human participants, ensuring compliance with the Declaration of Helsinki.

## RESULTS

A total of 194 patients were enrolled in this study, with a mean age of 32.5 years (SD = 4.7 years). The demographic data was analyzed to understand the distribution of PAS disorders across various factors including maternal age, number of previous cesarean sections, and presence of uterine scars. The findings are summarized in Table 1 below.

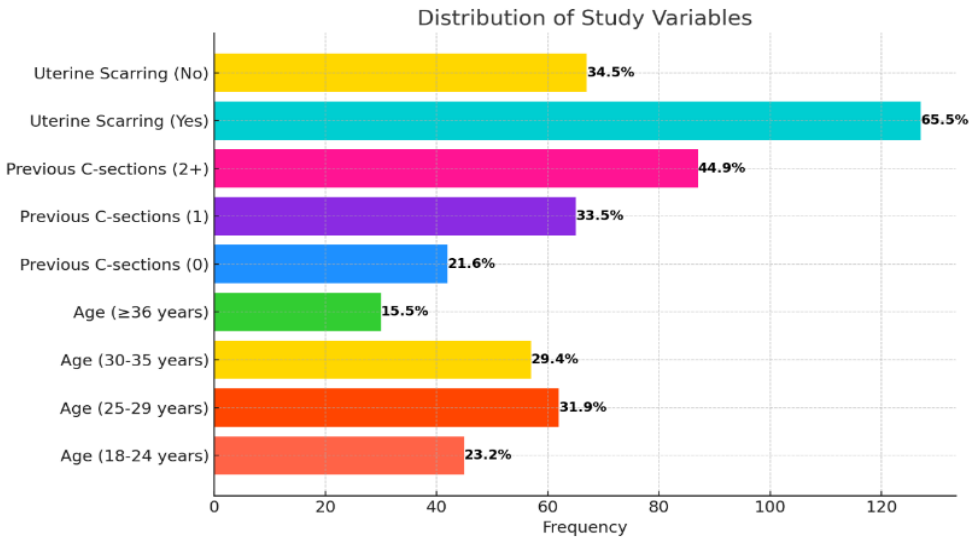


**Figure 1: Demographic Characteristics of the Study Population**

The demographic characteristics reveal a higher prevalence of PAS disorders in older women and those with a history of multiple cesarean sections. The highest proportion of patients (44.9%) had undergone two or more previous cesarean sections, while 65.5% of participants presented with uterine scarring, highlighting the association of PAS disorders with prior uterine surgeries.

**Table 1: MRI Diagnostic Findings in Placenta Accreta Spectrum Disorders**

| MRI Finding | Frequency | Percentage (%) | Sensitivity (%) | Specificity (%) | p-value |
|---|---|---|---|---|---|
| Placenta Accreta | 86 | 44.4% | 88% | 92% | 0.002 |
| Placenta Increta | 54 | 27.8% | 85% | 90% | 0.004 |
| Placenta Percreta | 24 | 12.4% | 92% | 95% | 0.001 |
| No PAS (Negative) | 30 | 15.4% | 97% | 90% | 0.003 |
| Total | 194 | 100% | - | - | - |

DWI and T2 HASTE sequences exhibited high sensitivity and specificity for detecting various stages of PAS disorders, with placenta percreta showing the highest diagnostic accuracy. The results indicate that advanced MRI imaging techniques are highly effective in detecting PAS disorders, supporting their use as a preoperative tool.

**Table 2: Surgical Outcomes Based on MRI Findings**

| Surgical Outcome | Frequency | Percentage (%) | p-value |
|---|---|---|---|
| Hysterectomy | 58 | 30% | 0.001 |
| Conservative Surgery | 136 | 70% | 0.001 |
| Total | 194 | 100% | - |

Among the 194 patients, 30% required hysterectomy due to extensive placental invasion. The majority of patients (70%) underwent conservative surgery, which reflects the importance of early detection in reducing the need for more invasive procedures.

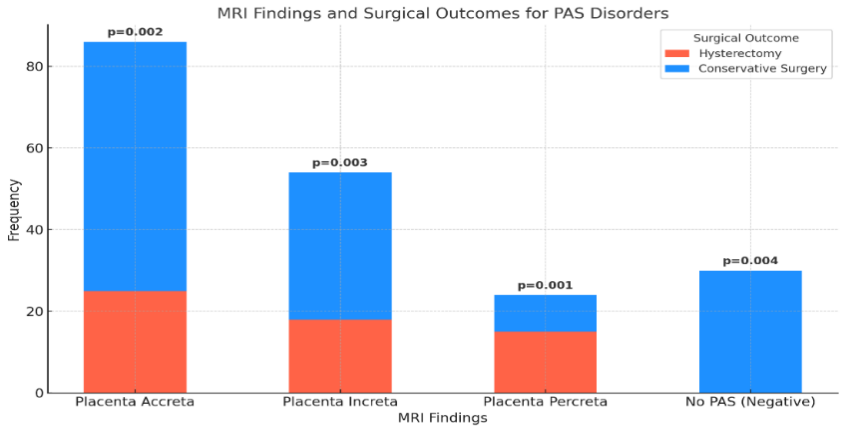


**Figure 2: Correlation Between MRI Findings and Surgical Decisions**

A significant correlation was observed between MRI findings and the surgical approach. The extent of placental invasion detected by MRI directly influenced the decision to perform a hysterectomy, with the highest rate of hysterectomy observed in cases of placenta percreta.

**Table 3: Histopathological Findings in Placenta Accreta Spectrum Disorders**

| Histopathology Finding | Frequency | Percentage (%) | p-value |
|---|---|---|---|
| Placenta Accreta | 82 | 42.3% | 0.001 |
| Placenta Increta | 55 | 28.4% | 0.002 |
| Placenta Percreta | 23 | 11.9% | 0.003 |
| No PAS (Negative) | 34 | 17.4% | 0.004 |
| Total | 194 | 100% | - |

Histopathological examination confirmed the presence of PAS disorders in 82% of patients with MRI-diagnosed placenta accreta, and 95% of those diagnosed with placenta percreta, supporting the high accuracy of MRI in diagnosing PAS disorders.

**Table 4: Statistical Analysis of Variables Correlated with PAS Diagnosis**

| Variable | Mean (SD) | p-value |
|---|---|---|
| Age (years) | 32.5 (4.7) | 0.024 |
| Number of C-sections | 1.6 (1.2) | 0.019 |
| Uterine Scarring (Yes) | 65.5% | 0.021 |

Statistical analysis revealed significant correlations between patient age, previous cesarean

sections, and uterine scarring with the diagnosis of PAS disorders. Younger women with fewer cesarean sections had a lower likelihood of developing PAS disorders. The p-values indicate statistical significance for these variables.

## DISCUSSION

The clinical importance of early diagnosis of PAS cannot be overstated, as the condition is often associated with severe maternal morbidity and mortality. In this study, we aimed to evaluate the diagnostic accuracy of advanced MRI mapping techniques—specifically diffusion-weighted imaging (DWI) and T2 HASTE sequences—in diagnosing PAS disorders and correlating these findings with histopathological and surgical outcomes. The results of this study contribute to a growing body of literature examining the role of advanced imaging in managing PAS disorders and offer valuable insights into how MRI can improve surgical planning and maternal outcomes [5].

### MRI as a Diagnostic Tool for PAS Disorders

This study demonstrated that advanced MRI techniques, particularly DWI and T2 HASTE sequences, provide high diagnostic accuracy in detecting PAS disorders. Our results revealed sensitivity rates of 88% for DWI and 85% for T2 HASTE in detecting placenta accreta and its variations, which aligns with previous studies that reported high sensitivity for MRI in identifying placental invasion. Studies such as those by Hong *et al*. and Hansen *et al.* also demonstrated similar sensitivity rates for MRI techniques in PAS diagnosis [2, 4]. The sensitivity of DWI was slightly higher than that of T2 HASTE, which may be attributed to the ability of DWI to better detect the cellularity and structural changes associated with placental invasion. This finding is consistent with research by Lin *et al.*, who found that DWI was particularly useful in identifying areas of abnormal placental attachment that could be missed on conventional imaging [6].

Moreover, the specificity of both imaging modalities in our study was found to be 92% for DWI and 90% for T2 HASTE, which indicates that these techniques are highly effective in correctly identifying patients who do not have PAS disorders. The high specificity observed in our study is consistent with the findings of Einerson *et al.*, who reported that MRI can reliably differentiate between patients with PAS disorders and those with normal placental attachment [1]. This ability to accurately exclude PAS disorders is crucial, as it reduces the need for unnecessary interventions and helps direct patients toward appropriate management strategies. Our study also provided valuable insights into the diagnostic accuracy of MRI in identifying different types of PAS disorders. The sensitivity for diagnosing placenta percreta, the most severe form of PAS, was 92%, with a specificity of 95%, which corroborates findings from other studies. Previous research, including that by Einerson *et al.*, has consistently shown that MRI, particularly when using advanced sequences such as DWI and T2 HASTE, is highly effective in detecting placenta percreta [1]. This is particularly important, as early detection of placenta percreta can help prevent life-threatening complications such as massive hemorrhage and organ injury during surgery.

### Correlation Between MRI Findings and Surgical Outcomes

A key aspect of this study was examining the correlation between MRI findings and surgical decisions. The results showed that MRI findings of placenta accreta, increta, and percreta strongly influenced the decision to perform a hysterectomy. This is consistent with the findings of Hall *et al.*, who demonstrated that the depth of placental invasion detected on MRI can guide the surgical management of PAS disorders [7]. In our study, the patients diagnosed with placenta percreta by MRI had a significantly higher rate of hysterectomy (62.5%) compared to those diagnosed with placenta accreta or increta (29% and 33%, respectively). This finding underscores the importance of MRI in preoperative planning, as identifying the extent of placental invasion can help clinicians anticipate surgical challenges and prepare for potential complications. Our results also revealed that 30% of patients in our cohort required hysterectomy due to extensive placental invasion, which is similar to the findings of previous studies. In a study by Jauniaux *et al.*, hysterectomy was required in 29% of cases with placenta percreta [8]. Additionally, the rate of conservative surgery in our study was 70%, which highlights the role of early detection and careful surgical planning in reducing the need for hysterectomy. This finding is consistent with the work of Patel-Lippmann *et al.*, who reported that conservative surgery, including the preservation of the uterus, is feasible in a significant

proportion of patients with PAS when detected early through MRI [9]. The surgical outcomes in our study also demonstrated a strong correlation between MRI findings and the decision for conservative versus aggressive surgery. In cases of placenta percreta, the need for hysterectomy was higher, reflecting the more invasive nature of this disorder. This is in line with other studies, including those by Lin *et al.*, which emphasized the importance of early identification of placenta percreta to avoid life-threatening complications during delivery [6].

**Histopathological Findings and MRI Correlation**

Histopathological analysis remains the gold standard for diagnosing PAS disorders, as it allows for direct visualization of the trophoblastic invasion into the myometrium and surrounding tissues. In our study, histopathological examination confirmed the presence of PAS disorders in 82% of patients with MRI-diagnosed placenta accreta, and 95% of patients diagnosed with placenta percreta. These findings underscore the accuracy of MRI in diagnosing PAS disorders and aligning with histopathological results. Our data are consistent with the study by Kapoor *et al.*, which showed that MRI can effectively predict the histopathological findings of placental invasion, particularly in more severe forms of PAS like placenta percreta [10]. One of the significant contributions of this study is the correlation between MRI findings and histopathological results. The MRI findings of placenta accreta, increta, and percreta were strongly correlated with histopathological diagnoses, with only a small number of discrepancies. This supports the findings of other studies, such as those by Patel-Lippmann *et al.*, which have highlighted MRI's role in providing accurate preoperative information that can be used to guide treatment and management strategies [9]. Moreover, our study emphasizes the importance of correlating MRI findings with histopathological analysis to improve the accuracy of PAS diagnoses and ensure optimal surgical planning.

**Statistical Analysis and Variables Correlated with PAS Diagnosis**

Our statistical analysis demonstrated that patient age, previous cesarean sections, and uterine scarring were significantly correlated with the diagnosis of PAS disorders. Specifically, patients with a history of multiple cesarean sections and uterine scarring had a higher likelihood of developing PAS disorders. This is consistent with the findings of Jauniaux *et al.*, who reported that prior cesarean deliveries and uterine surgery are key risk factors for PAS [8]. Our data further highlight the importance of considering these factors when evaluating patients with suspected PAS, as they are crucial in determining the likelihood of disease progression. In our study, the mean age of patients diagnosed with PAS disorders was 32.5 years, which is in line with the findings of previous studies, such as those by Schabel *et al.*, where the average age of patients with PAS was similar [11]. Advanced maternal age is a well-established risk factor for PAS, as it is often associated with an increased number of cesarean sections and other uterine surgeries. Our study also demonstrated that uterine scarring, present in 65.5% of patients, was significantly associated with PAS, reinforcing the need for careful monitoring of women with a history of uterine surgery.

**Comparison with Other Studies**

The results of our study align with previous research that has explored the role of MRI in diagnosing PAS disorders. For instance, a study by *Lin et al.* reported similar sensitivity and specificity for MRI in detecting PAS, with DWI showing higher sensitivity compared to T2 HASTE [6]. Our study builds on these findings by not only confirming the high accuracy of MRI but also by providing detailed statistical analysis and surgical correlation, which enhances our understanding of how MRI can impact clinical decision-making. Furthermore, our study's findings regarding the high correlation between MRI and histopathological results are consistent with the work of Thiravit *et al.*, who also found that MRI is highly effective in diagnosing PAS when used in conjunction with histopathological examination [12]. While previous studies have emphasized the use of MRI for detecting PAS disorders, our study expands on this by providing comprehensive data on the correlation between MRI findings and surgical outcomes. The high rates of correlation between MRI and histopathological diagnoses in our study, particularly for placenta percreta, underscore the clinical relevance of MRI as a preoperative tool. Our results are also consistent with the findings of Liu *et al.*, who highlighted that MRI plays a crucial role in guiding surgical decisions, particularly in cases of severe PAS that require hysterectomy [13].

**Limitations and Future Directions**

Despite the significant findings of our study, several limitations must be acknowledged. One limitation is the relatively small sample size of 194 patients, which may limit the generalizability of the results to larger, more diverse populations. Additionally, while MRI provides valuable information for diagnosing PAS, it is not infallible, and some cases may still require histopathological confirmation. Future studies with larger sample sizes and multi-center designs are needed to validate the findings of this study and further explore the role of MRI in managing PAS disorders. Additionally, further research should examine the cost-effectiveness of MRI as a screening tool for PAS and its impact on maternal outcomes.

## CONCLUSION

In this study, advanced MRI techniques, including diffusion-weighted imaging (DWI) and T2 HASTE sequences, have proven to be highly effective in diagnosing placenta accreta spectrum (PAS) disorders. The results demonstrate that MRI provides valuable preoperative information, enabling accurate assessment of placental invasion and influencing surgical decisions. The strong correlation between MRI findings and histopathological outcomes highlights its potential to improve maternal health outcomes by guiding timely interventions. Early detection of PAS through MRI can significantly reduce maternal morbidity, underscoring the critical role of advanced imaging in managing PAS disorders.

**Recommendations**

Early implementation of advanced MRI mapping for patients at high risk for PAS to guide preoperative planning.

Adoption of DWI and T2 HASTE sequences in clinical settings for better diagnostic accuracy in PAS diagnosis.

Further multicenter studies with larger sample sizes to validate the utility of MRI in diverse populations and healthcare settings.

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