Additional Role of Magnetic Resonance Imaging to Ultrasound in Assessing Placenta Accreta Spectrum Disorders: A Retrospective Cross-Sectional Study from Vietnam

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Abstract

Objectives: Placenta accreta spectrum (PAS) relates commonly to adverse outcomes during pregnancy. Aside from ultrasound (US), the role of magnetic resonance imaging (MRI) remains important in assessing PAS disorders. This study aimed mainly to reveal the features of MRI and to enhance the adjunct role of MRI to US imaging in PAS management. Additionally, the study purposed to investigate the association between imaging modalities and clinical outcomes.

Methods: This retrospective cross-sectional study was conducted between January 2017 and June 2022 at Tu Du Hospital, Vietnam. The study enrolled 87 cases eligible for inclusion criteria. The antenatal MRI and US findings was compared to the intraoperative diagnosis and/or histopathological confirmation as gold standard. The value of each MRI sign was calculated. The association between MRI/US and estimated blood loss/surgical methods were relevant. Statistical tests were used where appropriate and P-value < 0.05 was considered significant.

Results: Out of eighty-seven pregnant women who were suspected of PAS on ultrasound. Eighty-three cases were confirmed with PAS in terms of intraoperative diagnosis and/or by histology. The mean maternal age was 35.9 ± 5.7 (years) and the mean gestational age at cesarean section was 31.1 ± 7.1 (weeks). Overall, the value of PAS diagnosis according to each sign on MRI had a sensitivity (Se) between 10.8% and 94.0% and a specificity (Sp) from 25.0% to 100.0%. Noticeably, focal interruptions in the myometrial wall had the greatest value. Using 3-6 signs, the Se and Sp of MRI examination increased from 53.0% to 100.0% and from 25.0% to 100.0%, respectively. The highest Youden's index of 0.759 was noted with five MRI signs (Se: 75.9%, Sp:100.0%). The antenatal diagnosis with/without PAS on MRI and US linked to greater massive hemorrhage in CS (1000 [600-2000] ml vs. 500 [250-850] ml and 1000 [600-2000] ml vs. 300 [300-500] ml, respectively). In addition, the PAS type of percreta through MRI and US findings increases significantly the rate of cesarean hysterectomy versus conservative surgery (56.4% vs. 43.6% and 63.5% vs. 36.5%, respectively).

Conclusion: MRI demonstrates a reliable value in diagnosing PAS disorders following equivocal US. The step-by-step approach of these imaging modalities could be taken into account depend on the availability of resource-settings. The PAS diagnosis on MRI following US, especially PAS type percreta ought to be required for a strict interdisciplinary

management. Further data is necessary to emphasize the value of MRI in selected patients with severe form of PAS disorders.

Keywords: cesarean section, magnetic resonance imaging, postpartum hemorrhage, placenta accreta spectrum, ultrasound.

Introduction

Placenta accreta spectrum (PAS) is characterized by abnormal adhesion of the placenta, which can be subdivided into 3 types involving the degree of invaded depth into myometrium and extrauterine structures (accreta, increta, and percreta). Therefore, this pathology commonly causes massive bleeding during delivery, leading to a pre-delivery ruptured uterus and adverse neonatal outcomes.[1,2] Importantly, this catastrophic hemorrhage increases high rate of maternal mortality during pregnancy.[3] Moreover, pregnant women could face to cesarean hysterectomy since the success rate of conservative uterine surgery remains different following resource-settings and surgeon's skill.[4,5] The incidence of PAS is approximately 1.1% and is increasing rapidly due to the high rate of cesarean delivery and the common application of assisted reproductive technology.[6,7] In pregnant women with a greater number of prior cesarean scar and placenta previa, the incidence of PAS is higher.[1,8,9] Crucially, the PAS disorders could be also present among unsuspected pregnant women with lower risk of PAS development in order to be detected by antenatal US screening.[10,11] Particularly, PAS disorders on an unscarred uterus have been recently documented.[12,13]

Using imaging modalities, a prenatal diagnosis of severe PAS could prevent adverse materno-fetal outcomes and helps in selecting the surgical intervention of either hysterectomy or uterine-preserving surgery.[14,15] The PAS scoring system helps stratify patients into low, intermediate, and high-risk categories for placenta accreta.[16] Universally, early diagnosis and timely management contribute significantly to reducing the estimated blood loss, avoiding maternal death in labor, and increasing the successful rate of conservative management.[8,17] To date, some imaging modalities are attributable to detect PAS disorders, even in the first trimester of pregnancy.[6,18]

Among pregnant women with low-lying or placenta previa with previous cesarean section scar, ultrasound scan helps in diagnosing PAS with the overall sensitivity and specificity were 0.8703 and 0.8634, respectively.[19] According to several findings, ultrasonography can be superior to MRI and sufficient for the diagnosis of PAS, limiting the use of MRI to a few doubtful cases requiring surgical planning.[20,21] Likewise, the interobserver agreement remains suboptimal for both modalities.[14] The ultrasound as primary imaging tool could ignore the PAS when the placenta is located at the posterior site or the pregnant woman has no previous uterine scar.[6] Consequently, the inaccurate evaluation of abnormal placentation places the obstetricians in an emergency condition as well as the patient in a critically life-threatening condition due to inappropriate preparation. Recently, Kolak et al. has underscored that the interpretation of the ultrasound signs following the findings of Sargent et al. may be difficult to be applied universally. Therefore, the development of any new predictive models of PAS in US ought to be a concern.[22]

Regarding the suspected cases on ultrasound, MRI increases the diagnostic value of PAS. Particularly, this imaging assessment evaluates accurately the invasive depth, the invasion into surrounding structures, and the topography of placental invasion.[23-25] According to Fiocchi et al., MRI showed 100% sensitivity (95% CI = 75.3-100.0%) and 92.3% specificity (95% CI = 64.0-100.0%) in the diagnosis of invasive placentation.[24] Similarly, various studies have demonstrated the same evidence.[23]

However, the study relating to the value of MRI in low-middle income countries remains unknown due to the limited-resource settings. Through this current study, we aimed mainly to reveal the features of MRI and additional role of MRI in PAS assessment before surgery. Secondly, the purpose of study was to evaluate the clinical outcomes following imaging modalities at our tertiary center.

Methods

This retrospective cross-sectional study was conducted between January 2017 and June 2022 at Tu Du Hospital, in southern Vietnam. The study enrolled all the pregnant women who were suspected with placenta accreta spectrum (PAS) on ultrasound (US). These patients underwent magnetic resonance imaging (MRI) examination and cesarean section (CS) using conservative uterine surgery or hysterectomy depending on practical indication. The diagnosis of US/MRI detection

was compared to intraoperative diagnosis and/or using the histopathological confirmation in conservative uterine surgery or cesarean hysterectomy.[17]

Exclusion criteria consist of missing patient's file, insufficient description of MRI signs, and absence of PAS identification by surgery or by histology (Figure 1). This study followed the STROCSS (Strengthening the Reporting of Cohort Studies in Surgery) 2021 checklist for cross-sectional studies.[26]

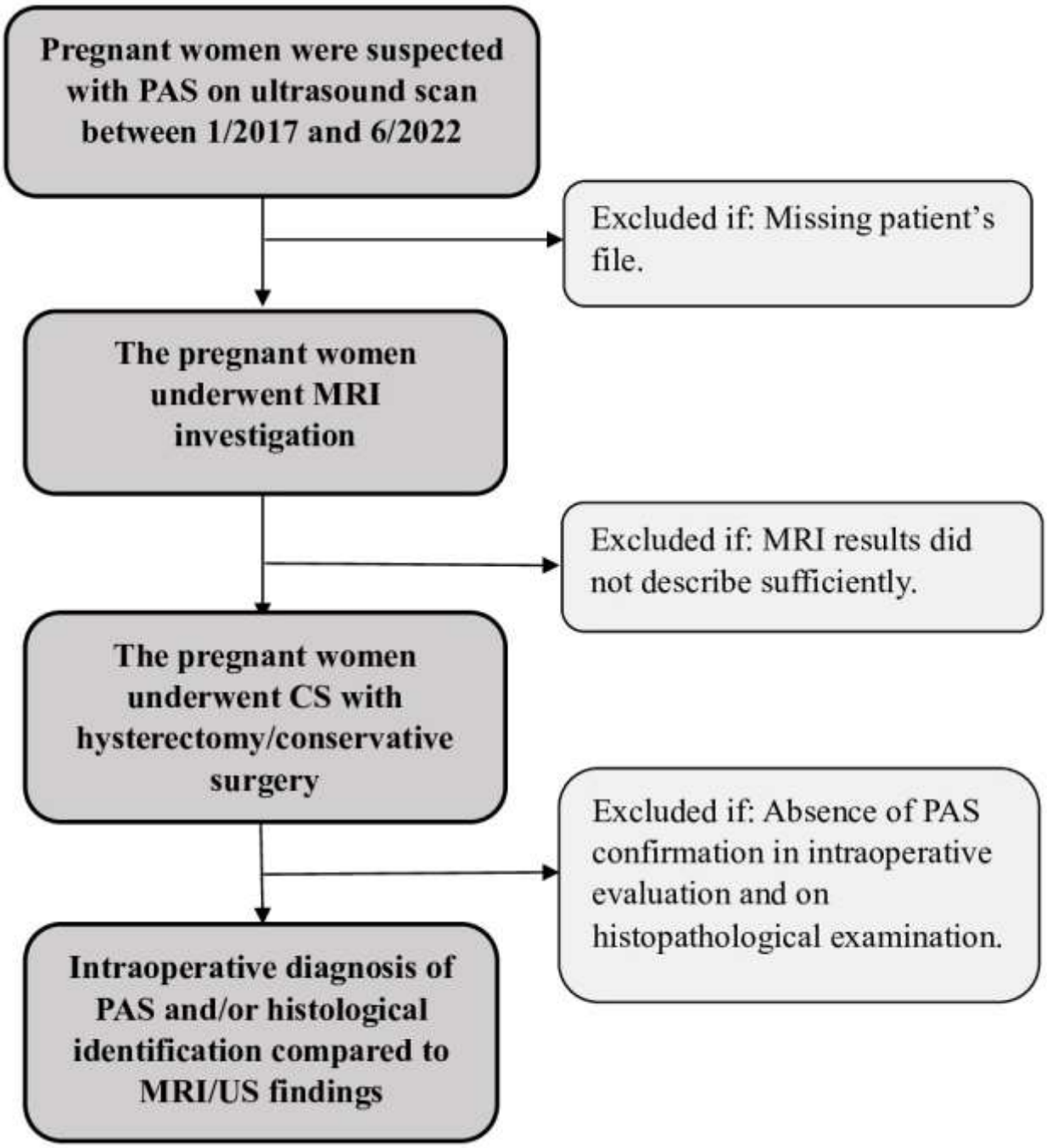

Figure 1: Study flowchart of the present study.

At laparotomy, the definitive diagnosis of PAS was carefully evaluated after placental delivery by experienced surgeons (over 10 years) at our center, following the International Federation of Gynecology and Obstetrics (FIGO) consensus.[27]

-Grade 1: Abnormally adherent placenta (placenta adherenta or accreta): Macroscopically, the uterus shows no obvious distension over the placental bed (placental "bulge"), no placental tissue is seen invading through the surface of the uterus, and there is no or minimal neovascularity.

- Grade 2: Abnormally invasive placenta (Increta): Abnormal macroscopic findings over the placental bed: bluish/purple coloring, distension (placental "bulge"); significant amounts of hypervascularity (dense tangled bed of vessels or multiple vessels running parallel craniocaudally in the uterine serosa); placental tissue seen to be invading through the uterine serosa; gentle cord traction results in the uterus being pulled inwards without separation of the placenta (so-called the dimple sign).

- Grade 3: Abnormally invasive placenta (Percreta): Abnormal macroscopic findings on uterine serosal surface (as above) and placental tissue seen to be invading through the surface of the uterus, with/without urinary bladder invasion, or with/without invasion of other pelvic tissue/organs.

According to the degree of placenta villi invasion, three types of PAS were classified on histology following the consensus of The International Federation of Gynecology and Obstetrics (FIGO).[27] Placenta accreta: Microscopic examination of the placental bed samples from the hysterectomy specimen shows extended areas of absent decidua between villous tissue and myometrium with placental villi attached directly to the superficial myometrium. Placenta increta: Hysterectomy specimen or partial myometrial resection of the increta area shows placental villi within the muscular fibers and sometimes in the lumen of the deep uterine vasculature (radial or arcuate arteries). Placenta percreta: Hysterectomy specimen showing villous tissue within or breaching the uterine serosa/ invading the bladder wall tissue or urothelium/ invading pelvic tissues/organs (with or without invasion of the bladder).

The sonographic diagnosis of PAS was established by the presence of at least two of the following criteria using standard two-dimensional grayscale/color Doppler transabdominal and transvaginal ultrasonography: (1) loss or irregularity of the echogenic area between the uterus and placenta; (2) thinning or interruption of the hyperechogenic interface between the uterine serosa and bladder wall, measured uterine myometrial thickness less than 1 cm; (3) presence of turbulent placental lacunae with high-velocity flow (>15 cm/s); (4) hypervascularity of the uterine serosa-bladder wall interface, or (5) irregular intraplacental vascularization characterized by tortuous confluent vessels across the placental width. All the patients were scanned using a Samsung HS40 scanner and the ultrasound scan was performed by an expert sonographer with more than 10 years of experience in the imaging field.[28,29]

The appearance of placenta accreta spectrum (PAS) on MRI was typically described according to the Inside Out Approach and the joint Society of Abdominal Radiology (SAR) and European Society of Urogenital Radiology (ESUR) guidelines on PAS disorders. MRI features, namely in terms of dark intraplacental band, heterogeneous placenta, placental bulge, lumpy contour/rounded edge, abnormal/disorganized placental vascularity/lacunae, thinning/loss of the retroplacental T2 dark zone, myometrial thinning, focal disruption of myometrium, bladder or adjacent structural invasion, and focal exophytic mass sign are categorized for diagnosing PAS disorders. Each MRI sign was given one point to calculate the total points following the scoring system.[30-34]

Figure 2 A-B-C-D shows all the features concerning placenta accreta spectrum on magnetic resonance imaging (MRI). Dark intraplacental band are described as wedge-shaped areas of low signal intensity on T2-weighted images. Heterogeneous placenta is described as marked heterogeneous intensity within the placenta. Placental bulge is described as a focal bulging of the uterine contour. A lumpy contour/rounded edge is described as a normal placenta has a smooth contour and tapering angled edges. The lumpy contour and rounded edge resulting from placental tethering are imaging features that can be identified in PAS disorders. Abnormal/disorganized placental vascularity/lacunae is described as tortuous enlarged flow voids observed on T2. Thinning/loss of retroplacental T2 dark zone is described as the placenta-myometrial interface is interrupted in PAS cases since it is detected on MRI as a loss of the retroplacental dark line on a T2-weighted image. This finding is usually associated with other signs, such as a focal myometrial defect and myometrial thinning. Myometrial thinning is described as thinning of the myometrium over the placenta to less than one mm or even invisible. Focal disruption of the myometrium is identified at the site of placental invasion.

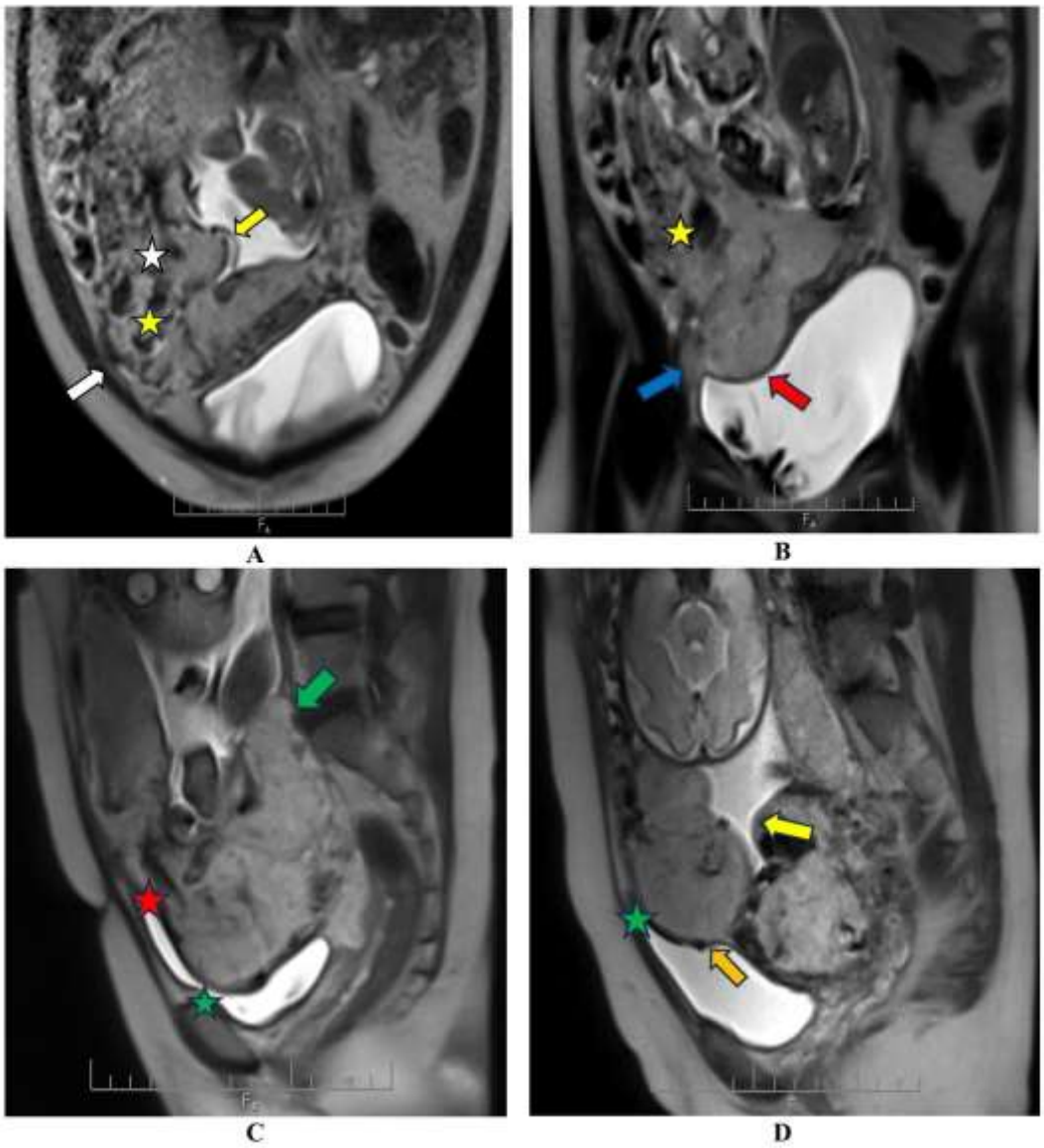

Figure 2: The features of magnetic resonance imaging (MRI) of placenta accreta spectrum (PAS) regarding different planes show: A (axial plane): Abnormal/disorganized placental vascularity (white star), heterogenous signal placenta (yellow star), focal exophytic mass (white arrow), and lumpy contour (yellow arrow). B (coronal plane): Heterogenous signal placenta (yellow star), focal interruption in myometrial wall (blue arrow), and loss of demarcation/ retroplacental T2 dark zone (red arrow). C (sagittal plane): Rounded edge (green arrow), intraplacental dark band (red star), and uterine bulging (green star). D (sagittal plane): Lumpy contour (yellow arrow), uterine bulging (green star), and thinning myometrial thickness (orange arrow).

The imaging features can be observed only when the myometrium is well depicted. The criteria for bladder extension includes the interruption of the bladder wall, tenting of the bladder dome, marked chaotic vascularity at the interface between the uterus and bladder, and focal placental tissue inside the bladder. Focal exophytic mass is defined as placental tissue protruding through the uterine wall and extending beyond it. Most commonly seen inside at least partially filled urinary bladder and laterally into the parametrium.[31,33,34]

MRI performance was carried out with a machine labeled Siemens Magnetom Espree 1.5 Tesla (USA). The technique used appropriately a pulse sequence of the T2 HASTE, T2FS, T1W, DW, ADC, and TrueFISP on the sagittal, coronal, and axial plane. The results were analyzed on computer by a more than 10-year experienced radiologist. This observer

was different from the one who performed an ultrasound. The MRI was performed before cesarean section about 1-2 weeks.

All data were retrieved from medical records. Continuous variables include maternal age (years), gestational age (weeks) at the first diagnosis of PAS, gestational age (weeks) at cesarean delivery, and estimated blood loss (ml). Categorical variables encompass residence, parity, history of cesarean section, number of uterine scar, history of curettage, vaginal bleeding symptom, hematuria, type of PAS on MRI/US, in surgery, and on histopathological examination, the location of placenta on MRI/US, surgical methods, estimated blood loss greater/less than 1500 ml, and all features of PAS on MRI. The type of PAS consists of placenta adherent to myometrial layer (Accreta, PAS 1), invasive to the myometrial layer (Increta, PAS 2), and invasive to the serosal layer (Percreta, PAS 3). The surgical methods including cesarean hysterectomy and conservative surgery (traditional approach and modified one step conservative surgery: MOSCUS) were performed following the intraoperative evaluation and the experience of the surgeon as well as the strict protocol of our hospital.[5,15,17]

The data was entered using Epidata 2.0 software and analyzed using the STATA 15.0 and the Statistical Package for the Social Sciences (SPSS) version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were expressed as means and standard deviations (X ± SD), and median and interquartile range (IQR) ([Q1-Q3] corresponding to the percentile of 25.0%-75.0%, using Tukey's Hinges) for quantitative variables depending on the distribution of data. Frequency data with percentages and comparison of categorical variables were performed across categories using the $\chi 2$ (chi-square test). If the counting variable has a theoretical number < 5 in each cell (> 25% of the table), the *p*-value is obtained by Fisher's exact probability test. Statistical tests were applied for nonparametric tests where appropriate. The odds ratio (OR) was calculated from the 2 × 2 Table. A probability value of $p < 0.05$ was considered statistically significant for all analyses.

The sensitivity and specificity of each MRI sign were calculated based on the number of PAS cases that were concordant and discordant with intraoperative diagnosis and/or histopathological confirmation. Youden's index was calculated by J= sensitivity + specificity – 1.

Results

A total of eighty-seven cases relating to suspected placenta accreta spectrum (PAS) on ultrasound met inclusion criteria. The intraoperative diagnosis and histopathological confirmation as golden standard criteria identified 83 cases with PAS and 4 cases without PAS. The median value of estimated blood loss (EBL) in PAS group is greater than in non-PAS group (1000 [600-2000] ml vs. 500 [250-850] ml). The amount of EBL greater than 1500 ml was recorded in all PAS pregnant women. However, the difference is not significantly statistical. All the baseline characteristics of the study population and their association with PAS diagnosis are shown in Table 1 and Appendix 1.

Table 1: Baseline characteristics of the study population.

Characteristics		PAS (N=83)	Non-PAS (N=4)	Total (N=87)
Maternal age (years)	mean ± SD	36.0 ± 5.7	35.3 ± 5.4	35.9 ± 5.7
	(min-max)	(28-41)	(21-47)	(21-47)
	21-30	13 (15.7)	1 (25.0)	14 (16.1)
	31-40	45 (54.2)	2 (50.0)	47 (54.0)
	41-50	25 (30.1)	1 (25.0)	26 (29.9)
Parity (times)	Nulliparous	2 (2.4)	0 (0.0)	2 (2.3)
	1	43 (51.8)	4 (100.0)	47 (54.0)
	2	31 (37.4)	0 (0.0)	31 (35.6)
	≥3	7 (8.4)	0 (0.0)	7 (8.1)
History of CS	No	6 (7.2)	0 (0.0)	6 (6.9)
	Yes	77 (92.8)	4 (100.0)	81 (93.1)
Number of CS (times)	1	49 (63.6)	4 (100.0)	53 (65.4)
	2	24 (31.2)	0 (0.0)	24 (29.6)
	≥3	4 (5.2)	0 (0.0)	4 (5.0)
Other uterine scar	No	81 (97.6)	4 (100.0)	85 (97.7)
	Yes	2 (2.4)	0 (0.0)	2 (2.3)
History of curettage	No	70 (84.3)	4 (100.0)	74 (85.1)

Vaginal bleeding	Yes	13 (15.7)	0 (0.0)	13 (14.9)
	No	70 (84.3)	3 (75.0)	73 (83.9)
Hematuria	Yes	13 (15.7)	1 (25.0)	14 (16.1)
	No	83 (100.0)	4 (100.0)	87 (100.0)
	Yes	0 (0.0)	0 (0.0)	0 (0.0)
Estimated blood loss (ml) median IQR [Q1-Q3] min-max		1000 [600-2000] (200-4800)	500 [250-850] (200-1000)	1000 [550-2000] (200-4800)
EBL (ml)	<1500	48 (57.8)	4 (100.0)	52 (59.8)
	≥1500	35 (42.2)	0 (0.0)	35 (40.2)
Surgical method	Cesarean hysterectomy	37 (44.6)	0 (0.0)	37 (42.5)
	Conservative surgery	46 (55.4)	4 (100.0)	50 (57.5)
Placental location on US	Anterior site	63 (75.9)	3 (75.0)	66 (75.9)
	Posterior site	11 (13.3)	1 (25.0)	12 (13.8)
	Lateral site	9 (10.8)	0 (0.0)	9 (10.3)
Placental location on MRI	Anterior site	52 (62.7)	1 (25.0)	53 (60.9)
	Posterior site	23 (27.7)	1 (25.0)	24 (27.6)
	Lateral site	8 (9.6)	2 (50.0)	10 (11.5)
GA at the first diagnosis of PAS (weeks)	mean ± SD		24.3 ± 6.8 (12-36)	
	< 14		8 (9.6)	
	14-28		48 (57.8)	
	≥ 28		27 (32.3)	
GA at CS (weeks)	mean ± SD		31.1 ± 7.1 (12.5-36.4)	
	< 34		61 (73.5)	
	34-36		16 (19.3)	
	≥ 36		6 (7.2)	
Intraoperative PAS diagnosis	No		4 (4.6)	
	Yes		83 (95.4)	
Type of PAS following intra-operative evaluation	Adherent to myometrial layer (Accreta or PAS 1)		8 (9.6)	
	Invasive to myometrial layer (Increta or PAS 2)		12 (14.5)	
	Invasive to serosal layer (Percreta or PAS 3)		63 (75.9)	
Histopathological examination identifying PAS[a]	No		2 (3.1)	
	Yes		62 (96.9)	
Type of PAS on histology	Accreta		1 (1.6)	
	Increta		25 (40.3)	
	Percreta		36 (58.1)	

CS: cesarean section, EBL: estimated blood loss, MRI: magnetic resonance imaging, GA: gestational age, PAS: placenta accreta spectrum, US: ultrasound.

[a]*Histopathological examination was confirmed depending on surgical methods with/without relevant specimen of myometrium containing invasive tissue of PAS.*

The most frequently observed MRI signs were placenta previa (70/87 cases) and loss of retroplacental T2 dark zone (78/87 cases). Table 2 reveals the value of PAS diagnosis according to each sign on magnetic resonance imaging (MRI). Overall, the sensitivity (Se) ranges from 10.8% to 94.0% and the specificity (Sp) is variable between 25.0% and 100.0%. Noticely, the Se and Sp of intraplacental dark bands and focal interruptions in myometrial wall were 77.1%, 100.0% and 80.7%, 100.0%, respectively. Appendix 2 shows the association between the placenta previa on MRI/US and the diagnosis of PAS.

Table 2: Value of each sign of magnetic resonance imaging in diagnosing placenta accreta spectrum disorders.

Features		**PAS (N=83)**	**Non-PAS (N=4)**	**Total (N=87)**	**Se (%)**	**Sp (%)**
Placenta previa	No	13 (15.7)	1 (25.0)	14 (16.1)	84.3	25.0
	Yes	70 (84.3)	3 (75.0)	73 (83.9)		
Loss of demarcation line/retroplacental T2 dark zone	No	5 (6.0)	2 (50.0)	7 (8.1)	94.0	50.0
	Yes	78 (94.0)	2 (50.0)	80 (91.9)		
Abnormal/disorganized placental vascularity	No	39 (47.0)	4 (100.0)	43 (49.4)	53.0	100.0
	Yes	44 (53.0)	0 (0.0)	44 (50.6)		
Uterine bulging	No	58 (69.9)	4 (100.0)	62 (71.3)	30.1	100.0
	Yes	25 (30.1)	0 (0.0)	25 (28.7)		
Bladder invasion	No	72 (86.7)	4 (100.0)	76 (87.4)	13.3	100.0
	Yes	11 (13.3)	0 (0.0)	11 (12.6)		
Thinning myometrial thickness	No	38 (45.8)	1 (25.0)	48 (55.2)	54.2	25.0
	Yes	45 (54.2)	3 (75.0)	39 (44.8)		
Intraplacental dark bands	No	19 (22.9)	4 (100.0)	23 (26.4)	77.1	100.0
	Yes	64 (77.1)	0 (0.0)	64 (73.6)		
Heterogeneous signal intensity within the placenta	No	29 (34.9)	1 (25.0)	30 (34.5)	65.1	25.0
	Yes	54 (65.1)	3 (75.0)	57 (65.5)		
Focal interruptions in myometrial wall	No	16 (19.3)	4 (100.0)	20 (23.0)	80.7	100.0
	Yes	67 (80.7)	0 (0.0)	67 (77.0)		
Lumpy contour and rounded edge	No	46 (55.4)	3 (75.0)	49 (56.3)	44.6	75.0
	Yes	37 (44.6)	1 (25.0)	38 (43.7)		
Maximal placental thickness > 50 mm	No	60 (72.3)	3 (75.0)	63 (72.4)	27.7	75.0
	Yes	23 (27.7)	1 (25.0)	24 (27.6)		

Focal exophytic mass sign	No	73 (88.0)	4 (100.0)	77 (88.5)	12.0	100.0
	Yes	10 (12.0)	0 (0.0)	10 (11.5)		
Tenting of bladder	No	74 (89.2)	4 (100.0)	78 (87.9)	10.8	100.0
	Yes	9 (10.8)	0 (0.0)	9 (10.3)		

PAS: placenta accreta spectrum, Se: sensitivity, Sp: Specificity.

Using a total of 3-6 signs, the sensitivity of MRI increased from 53.0% to 100.0%, and specificity increased from 25.0% to 100.0%. The study's findings revealed the highest Youden's index of 0.759 was found at five MRI signs (Se: 75.9%, Sp:100.0%) (see Table 3).

Table 3: Value of score system in evaluating placenta accreta spectrum disorders.

Number of signs		PAS N=83	Non-PAS N=4	Se (%)	Sp (%)	Youden's index
3 signs	≥ 3	83	3	100.0	25.0	0.250
	< 3	0	1			
4 signs	≥ 4	79	2	95.2	50.0	0.452
	< 4	4	2			
5 signs	≥ 5	63	0	**75.9**	**100.0**	**0.759**
	< 5	20	4			
6 signs	≥ 6	44	0	53.0	100.0	0.530
	< 6	39	4			

PAS: placenta accreta spectrum, Se: sensitivity, Sp: Specificity.

Additionally, the presence of PAS diagnosis on imaging modalities shows a greater EBL. The antenatal diagnosis with and without PAS on MRI and US related to the greater massive hemorrhage in CS (1000 [600-2000] ml vs. 500 [250-850] ml and 1000 [600-2000] ml vs. 300 [300-500] ml, respectively). In addition, the PAS type of percreta through MRI and US findings increases significantly the rate of cesarean hysterectomy versus conservative surgery (56.4% vs. 43.6% and 63.5% vs. 36.5%, respectively). The detailed results are shown in Table 4 and Figure 3.

Table 4: The association between imaging modalities and clinical outcomes in non-PAS and PAS pregnant women.

Imaging modalities		Estimated blood loss (ml) Median, interquartile [Q1-Q3] min-max	P-value
Diagnosis of PAS on US	Non-PAS	300 [300-500] (300-700)	**0.046**[a]
	PAS	1000 [600-2000] (200-4800)	
Type of PAS on US	Adherent to myometrial layer (Accreta)	1000 [300-1400] (200-2000)	**< 0.0001**[b]
	Invasive to myometrial layer (Increta)	600 [350-1200] (200-2500)	
	Invasive to serosal layer (Percreta)	1600 [800-2500] (200-4800)	
Diagnosis of PAS on MRI	Non-PAS	500 [250-850] (200-1000)	0.062[a]
	PAS	1000 [600-2000] (200-4800)	
Type of PAS on MRI	Adherent to myometrial layer (Accreta)	-	**0.002**[b]
	Invasive to myometrial layer (Increta)	700 [450-1200] (200-2500)	

	Invasive to serosal layer (Percreta)	1500 [800-2500] (200-4800)		
Imaging modalities		**Estimated blood loss (ml) N(%)**		P-value
		<1500	≥1500	
Diagnosis of PAS on US	Non-PAS	3 (100.0)	0 (0.0)	0.270[c]
	PAS	49 (58.3)	35 (41.7)	
Type of PAS on US	Adherent to myometrial layer (Accreta)	7 (77.8)	2 (22.2)	**0.003**[d]
	Invasive to myometrial layer (Increta)	19 (82.6)	4 (17.4)	
	Invasive to serosal layer (Percreta)	23 (44.2)	29 (55.8)	
Diagnosis of PAS on MRI	Non-PAS	4 (100.0)	0 (0.0)	0.145[c]
	PAS	48 (57.8)	35 (42.2)	
Type of PAS on MRI	Adherent to myometrial layer (Accreta)	1 (100.0)	0 (0.0)	**0.002**[c]
	Invasive to myometrial layer (Increta)	22 (81.5)	5 (18.5)	
	Invasive to serosal layer (Percreta)	25 (45.5)	30 (54.5)	

		Surgical methods		
Imaging modalities		**Cesarean hysterectomy**	**Conservative surgery**	**P-value**
Diagnosis of PAS on US	Non-PAS	0 (0.0)	3 (100.0)	0.258[c]
	PAS	37 (44.0)	47 (56.0)	
Type of PAS on US	Adherent to myometrial layer (Accreta)	1 (11.1)	8 (88.9)	**<0.0001**[d]
	Invasive to myometrial layer (Increta)	3 (13.0)	20 (87.0)	
	Invasive to serosal layer (Percreta)	33 (63.5)	19 (36.5)	

Diagnosis of PAS on MRI	Non-PAS	4 (28.6)	10 (71.4)	0.377[d]
	PAS	33 (45.2)	40 (54.8)	
Type of PAS on MRI	Adherent to myometrial layer (Accreta)	0 (0.0)	1 (100.0)	**0.005**[c]
	Invasive to myometrial layer (Increta)	6 (22.2)	21 (77.8)	
	Invasive to serosal layer (Percreta)	31 (56.4)	24 (43.6)	

MRI: magnetic resonance imaging, PAS: placenta accreta spectrum, US: ultrasound.
[a]: Independent Samples Mann-Whitney U Test (Exact Sig.; 2-sided test)
[b]: Independent-Samples Kruskal-Wallis Test (Asymptotic Sig (2-sided test))
[c]: Fisher's Exact Test (Exact Sig.; 2-sided)
[d]: Pearson Chi-Square Test (Exact Sig.; 2-sided)
Statistically significant p-values (< 0 .05) are written in bold.

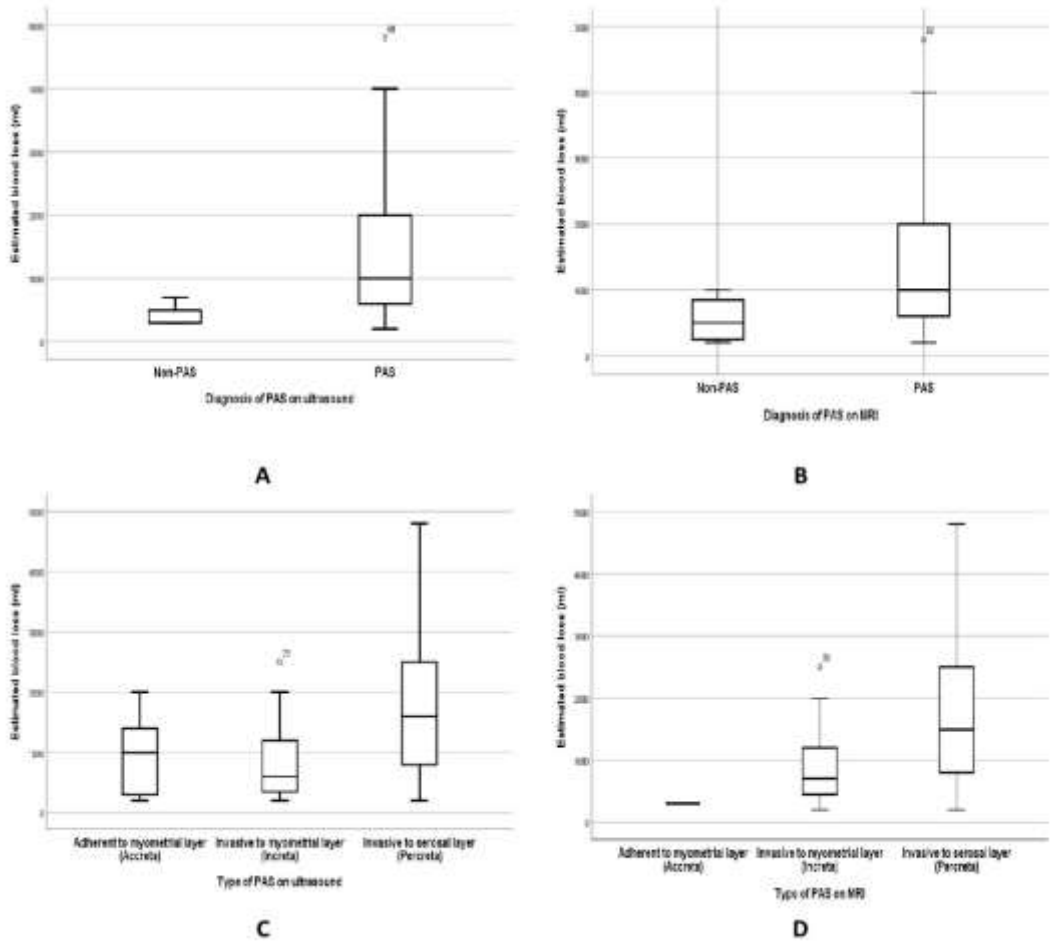

Figure 3: Box-plots show the association between the detection of PAS on imaging modalities and the estimated blood loss (ml) including diagnosis of PAS on ultrasound (US) and magnetic resonance imaging (MRI) (A-B) and type of PAS on US/MRI (C-D), respectively.

Discussion

In the present study, the findings revealed the different values of each feature when using the specific signs of PAS on MRI examination following the performation of ultrasound. The underlying pathology of PAS was demonstrated on imaging findings throughout the corresponding features.[18] The high sensitivity was found with the loss of retroplacental T2 dark zone and focal interruptions in the myometrial wall, 94.0% and 80.7%, respectively. Almost all signs were found with a high specificity of 75.0-100.0%, except for placenta previa, heterogeneous signal intensity within the placenta, and uterine bulging (25.0%). In the study of Niu et al., MRI signs such as myometrial thinning, loss of T2 hypointense interface, heterogenous intraplacental sign, and intraplacental T2 dark bands were more likely to be observed in PAS group.[35]

According to Mahalingam et al., loss of interface and thinning myometrium had the Se of 95.24% and the Sp of 87.18%.[16] In accordance with the study of Allameh et al., uterine bulging and heterogeneous signal intensity of placenta had the highest sensitivity of 0.89 and the specificity was 0.57 and 0.86, respectively.[36] In line with the findings of Thiravit et al., the sensitivity and the specificity of placental bulge sign were 94.4% (34/36 cases) and 84.6% (22/26 cases), respectively. Interobserver agreement analysis showed a kappa value for placental bulge of 0.48 for MRI and 0.40 for US. When combining placental bulge with subjacent dark intraplacental bands, the Se and Sp were 80.6% (29/36 cases) and 92.3% (24/26 cases), respectively.[14] Meanwhile, Romeo et al. have reported on seventy pregnant women in associated with PAS, by using multivariable analysis, the study showed that only intraplacental dark bands ($p = 0.012$) and focal interruption of myometrial border ($p = 0.029$) were independently associated with PAS disorders. The area under the ROC curve (AUC) in predicting PAS progressively increased using clinical risk factors (CRF), US, and MRI signs (0.69, 0.79, and 0.94, respectively; $p < 0.05$). The accuracy of MRI alone was similar to that obtained combining CRF, US and MRI variables (AUC = 0.97) and was significantly higher ($p < 0.05$) than that combining CRF and US (AUC = 0.83).[37] Similar to the study of Hu et al., the appearance of intraplacental T2-hypointense bands plays an important value in PAS detection, its invasion depth, and postpartum hemorrhage.[38]

In our findings, when combining cumulatively between 3 signs and 6 signs, value of MRI was different. The highest Youden's index was noted at 5 signs with Se of 75.9% and Sp of 100.0%. In consistent with Barzilay et al., at least 4/13 signs of MRI had a Se of 0.96 and a Sp of 0.6.[30] Overall, according the the findings of Lin et al., the combined Se, Sp, and AUC for the PAS diagnosis using MRI were 0.88 (95% CI, 0.79-0.93), 0.79 (95% CI, 0.68-0.87), and 0.91 (95% CI, 0.88-0.93), respectively.[39] In our study, eleven PAS cases were detected at the posterior site in the PAS group, this location may be a pitfall for ultrasound and its diagnosis may become inaccurate. In a systematic review, the meta-analysis revealed a sensitivity of 0.833 (95% CI, 0.776–0.878) and specificity of 0.834 (95%CI, 0.746–0.897) for ultrasound. Regarding MRI, the sensitivity was 0.838 (95% CI, 0.786–0.879) and the specificity was 0.831 (95% CI, 0.770–0.878). There was no statistically significant difference between the two imaging modalities.[40]

However, according to Romeo et al., MRI performance is the best modality to predict PAS in patients with placenta previa independently from clinical risk factors and/or US findings. Thus, clinical evaluation and US assessment should be considered as the first diagnostic level to predict PAS, MRI ought to be indicated only for selected cases after stratification in which US findings are uncertain for PAS.[37] Specifically, MRI has the advantages of superior soft tissue resolution, large imaging range and is currently an important and more advanced examination method for the diagnosis of PAS. Moreover, MRI examination is superior to the US when the placenta is located at the posterior site, because the placenta is hardly visualized by ultrasound.[35,41] The imaging pitfalls in sonographic evaluation of PAS disorders could be minimized when MRI serves as a complementary modality.[8]

Additionally, MRI examination could be used when the diagnosis is equivocal and helps in evaluating the extent and topography of myometrial invasion for surgical planning in abnormally invasive placenta focusing severe cases.[34,42,43] Most recently, Niu et al. has demonstrated that MRI is particularly helpful in dilemma cases using US and to evaluate the dimension of placenta and the invasion of the placenta into uterine serosa and to the surrounding organs.[35]

In our findings, the diagnosis of PAS on MRI/US was strongly associated with the massive estimated blood loss and increased the risk of cesarean hysterectomy during PAS surgery. Seriously, the PAS type percreta on MRI was more associated with greater EBL ≥ 1500 ml (29 cases) and requiring for cesarean hysterectomy (31 cases). Accordingly, 33 out of 50 PAS pregnant women undergoing cesarean hysterectomy has been recently documented.[35] Similarly, a half of PAS pregnant women (41/82 cases) was reported with cesarean hysterectomy in the study of Do et al.[44] Thereafter, Zhang et al. have proposed that pregnant women suspected of a high risk of intraoperative hemorrhage on MRI detection should

be managed a strictly antenatal management in late pregnancy and needing a preparation of blood transfusion, to improve the pregnancy outcomes.[45] In a suspected high-risk group for PAS, MRI identified more patients who will not need a hysterectomy than when using the ultrasound-based PAS index only. MRI helps in patient counseling, surgical planning, and delivery timing, including preterm delivery decisions for patients with PAS requiring hysterectomy.[44]

Although the study concerning the value of MRI in PAS diagnosis has been documented worldwide, this paper highlights the features and role of MRI in the Vietnamese population. Since our hospital is an expertise center which manages the transferred cases of PAS, thus the study could collect sufficiently the data.

Importantly, the study described the appearances of PAS on MRI according to the imaging signs which were validated in other populations. MRI investigation was performed using a unique machine and the result was read by one radiologist. Thus, the study could be reliable. Moreover, MRI diagnoses were compared with the histopathological result or intraoperative evaluation or with both. Therefore, a definitive diagnosis was highly accurate.

However, there appears to be a selection bias towards a higher grade of PAS in the retrospective study. Since our hospital is a tertiary referral hospital which manages the severe cases of PAS, thus the rate of placenta percreta is substantially high. The bias in selected cases following ultrasound scan could lead to the different proportion of MRI signs. Additionally, the observer was not blinded to ultrasound findings. Thus, the study could not guarantee the the optimal diagnosis.

In the future, we should conduct a study concerning the value of MRI and US in PAS grade 3 according to FIGO clinical classification with the diagnosis of separate sonographer and radiologist as well as evaluating its correlation with clinical outcomes. In addition, other prospective studies with a large number of PAS cases are required to compare the diagnosis of MRI and US by two independent radiologists. Based on clinical factors, ultrasound imaging, and MRI features, the future study could develop a predictor model to predict severe outcomes of PAS surgery among high-risk pregnant women.

Conclusion

In summary, each MRI feature had a different value in diagnosing PAS disorders. Among them, focal interruptions in the myometrial wall had the greatest value. Additionally, using the scoring system, the PAS diagnosis of MRI had the highest value at 5 signs. In suspected cases of PAS on ultrasound scan, the combination of MRI contributes to increasing the accuracy of detection. Moreover, the presence of PAS diagnosis on MRI/US, PAS type percreta implemented severely to the greater amount of intraoperative blood loss and the number of cases requiring for cesarean hysterectomy. Thus, these imaging tools should be ideally encountered in PAS management to guide timely preoperative surgical planning and make a greater impact on the patient's care where applicable. Further studies are promptly required to strengthen the use of MRI where necessary in clinical scenario.

Disclosure

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Appendix

Table 1: The association between clinical characteristics and diagnosis of placenta accreta spectrum.

Characteristics	PAS	Non-PAS	OR	P-value*

		N (%)	N (%)	95%CI	
Age (years)	21-30	13 (92.9)	1 (7.1)	1	
	31-40	45 (95.7)	2 (4.3)	1.73 (0.1-20.6)	0.664
	41-50	25 (95.4)	1 (4.6)	1.92 (0.1-33.3)	0.063
Residence	Others	66 (97.1)	2 (2.9)	3.88 (0.3-56.0)	0.163
	HCM city	17 (89.5)	2 (10.5)	1	
Previous cesarean scar	Yes	77 (95.1)	4 (4.9)	NA+	0.747
	No	6 (100.0)	0 (0.0)		
History of D&C	Yes	13 (100.0)	0 (0.0)	NA+	0.517
	No	70 (94.6)	4 (5.4)		
Vaginal bleeding	Yes	13 (92.9)	1 (7.1)	0.56 (0.04-31.5)	0.619
	No	70 (95.9)	3 (4.1)	1	
EBL (ml)	<1500	48 (92.3)	4 (7.7)	NA+	0.145
	≥1500	35 (100.0)	0 (0.0)		
Surgical methods	Cesarean hysterectomy	37 (100.0)	0 (0.0)	NA+	0.133
	Conservative surgery	*46 (92.0)*	*4 (8.0)*		

CI: Confidence intervals, D&C: dilation and curettage, HCM: Ho Chi Minh, OR: odds ratio, PAS: placenta accreta spectrum.
**Fisher exact's test*
+ *Not applicable since one cell contained the "zero" value.*

Table 2: The association between location of placenta on imaging modalities and diagnosis of placenta accreta spectrum.

Imaging modalities		**PAS N (%)**	**Non-PAS N (%)**	**OR 95% CI**	**P-value***
Placental site on US	Anterior	63 (95.4)	3 (4.6)		
	Posterior	11 (91.7)	1 (8.3)	NA+	0.590
	Lateral	9 (100.0)	0 (0.0)		
Placenta previa on US	No	15 (93.7)	1 (6.3)	1.51 (0.2-20.3)	0.727
	Yes	68 (95.8)	3 (4.2)	1	
Location of placenta on MRI	Anterior	52 (98.1)	1 (1.9)	1	
	Posterior	23 (95.8)	1 (4.2)	0.44 (0.03-7.4)	0.570
	Lateral	8 (80.0)	2 (20.0)	0.08 (0.0-0.9)	**0.045**
Placenta previa on MRI	No	13 (92.9)	1 (7.1)	1.80 (0.17-18.62)	0.511
	Yes	70	3	1	

(95.9) (4.1)

CI: Confidence intervals, MRI: magnetic resonance imaging, OR: odds ratio, PAS: placenta accreta spectrum, US: ultrasound.

**Fisher exact's test*

┼ Not applicable since one cell contained the "zero" value.

Statistically significant p-values (< 0 .05) are written in bold.