Novel markers of Doppler ultrasonography in the placenta accreta spectrum to predict complications

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Abstract

Objective: Ultrasonography (US) is an acceptable tool to diagnose the placenta accreta spectrum (PAS) among pregnant women. However, the lack of a robust criteria for diagnosis and predicting the severity of the consequences facing pregnant women requires identification of novel biomarkers.

Material and Methods: This prospective, cross-sectional study was performed on pregnant women with a probable diagnosis of PAS. Their demographic information, medical and surgical history, blood loss severity (severe ≥2500 mL) following hysterectomy, and the histopathology after the surgery were collected. In addition, the Doppler imaging of both uterine arteries, including the pulsatility index, resistance index, peak systolic velocity (PSV), the PSV of the posterior part of the bladder, cervix, the largest lacuna, and the posterior lacuna of the bladder were calculated by Doppler US. Data were analyzed to investigate the relationship between Doppler markers and the severity of PAS in terms of bleeding, hysterectomy, and histopathology.

Results: Fifty-one women were enrolled with a mean age of 35.4±4.11 years and 17 (33.3%) had severe bleeding. There were significant differences between median (range) bladder PSV [57 (34-90) vs. 33 (20-64); p<0.001], cervix PSV [26 (0-63) vs. 18 (0-76); p=0.04] and left uterine artery [89 (81-135) vs. 68 (61-113); p=0.045] for women with and without severe bleeding, respectively. Thirty-four (66.66%) had hysterectomy. Comparison of bladder PSV, cervix PSV, and left uterine PSV for women with and without hysterectomy were 46 (20-90) vs. 39.5 (33-46) (p=0.005), 20 (0-76) vs. 20 (14-26) (p=0.013) and 68 (61-135) vs. 82 (63-101) (p=0.003), respectively.

Conclusion: Bladder PSV, cervix PSV, and uterine PSV were significantly higher in pregnant women with PAS, and they may be useful diagnostic and prognostic markers. (J Turk Ger Gynecol Assoc 2023; 24: 228-34)

Keywords: Doppler ultrasonography, hysterectomy, hemorrhage, PAS, placenta accreta spectrum, PSV

Received: 24.04.2023 **Accepted:** 12.10.2023

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DOI: 10.4274/jtgga.galenos.2023.2023-2-10

Introduction

The placenta accreta spectrum (PAS) refers to unexpected adherence of the placenta to its implantation site. It includes accreta, increta, and percreta types. The pathoetiology is unknown but placenta previa and earlier uterine surgery have been reported to be significant risk factors for the condition (1,2). The rate of cesarean delivery, a relatively common uterine surgery, is increasing in many countries and this has been associated with an increase in the rate of PAS (3). The reported incidence of PAS is variable ranging from 0.91% (4) to 1 in 313 women with previous cesarean delivery (5). Obstetric bleeding and surgical issues, such as hysterectomy, are significant complications facing women with PAS. Furthermore, post-traumatic stress disorder, other psychological complications, and more prolonged hospital admission may occur among pregnant women with PAS (6).

Histopathology is the gold standard for diagnosing PAS (2) but ultrasonography (US) is common in diagnosing and evaluating the severity of the complications facing pregnant women. However, US is insufficient, especially in pregnant women with the posterior placenta (7). Magnetic resonance imaging may be an appropriate choice for pregnant women with PAS in whom evaluation is difficult with US (8).

In 2021 the Society for Maternal-Fetal Medicine (SMFM) suggested different sonographic markers for PAS for each trimester, such as cesarean scar and low implantation pregnancy in first trimester, placental lacuna, abnormal uteroplacental interface, abnormal uterine contour (placental bulge) and exophytic mass (9).

Doppler US is a method based on differences in ultrasound frequency when an object is moving and is a safe imaging method in pregnancy (10). Collins et al. (11) reported that markers produced during three-dimensional (3D) color Doppler sonography were effective for diagnosing PAS, and may be able to predict the severity. Moreover, Hussein et al. (12) showed that specific markers in 2D and 3D Doppler were able to predict the severity and consequences of hysterectomy and bleeding in pregnant women with PAS disorders. The SMFM considered bridging vessels (blood vessels lengthened from the placenta across the myometrium) as a Doppler US marker for PAS. Currently, the role of Doppler US for diagnosis of PAS is a research gap and requires more study to clarify (9).

In the present study, the aim was to investigate the role of Doppler US in pregnant women with PAS, specifically to identify and assess novel biomarkers using this modality that had diagnostic utility in identifying and predicting the severity of PAS. This will allow clinicians to choose the appropriate procedures to decrease morbidities and mortality among pregnant women with PAS.

Material and Methods

After Research Ethics Committees of Imam Khomeini Hospital Complex-Tehran University of Medical Sciences approval, this prospective cross-sectional study was performed in a tertiary referral center from September 2021 to August 2022 (approval number: IR.TUMS.IKHC.REC.1400.201, date: 01.09.2021). The study population was pregnant women with a suspicion of PAS. Women were referred to this center, after confirmation of likely PAS by two experienced experts and registering the PAS referral criteria were recorded. Informed consent was obtained from all participants for inclusion in the study. First, participants' demographics and medical history were collected, including obstetrics, abortion, medical and surgical history. In addition, history of cesarean section and reasons, history of gynecological and/or uterine surgery (especially myomectomy), and history of cesarean scar pregnancy were recorded. The study excluded women with severe anemia, coagulopathies, emergency status, and severe bleeding before delivery, such as placenta abruption.

One expert perinatal fellow performed the sonography using a Philips affinity 70 system before the surgery based on accreta in familial mediterranean fever. The sonography was performed transabdominally by positioning the probe vertically without pressure on the pubic symphysis with a full bladder. After locating the placenta and associated structures, Doppler assessment of the right and left uterine arteries, including the pulsatility index, resistance index (RI), and peak systolic velocity (PSV) were calculated. In addition, the PSV of the posterior part of the bladder, cervix, the largest lacuna, and the posterior lacuna of the bladder were measured. During uterine Doppler measurement, the probe was positioned parallel to the woman's sagittal axis (parasagittal) and perpendicular to the location of the bladder.

All pregnant women in this study delivered electively between 34 to 37 weeks of gestational age, based on placental position, especially placenta previa, the severity of accreta, and pregnant women's symptoms, including hematuria. All cesarean sections were performed by two expert surgeons, who also undertook hysterectomies in cases of uncontrolled bleeding when the uterus could not be preserved. In addition, all abdominal incisions were performed using Maylard incisions, and myometrial incisions were vertical in the cases of the placenta previas and Kerr in non-previa types.

Weighing drain sheets and gauzes before and after the surgery was used to calculate the average blood loss for each pregnant woman. In order to avoid miscalculation of blood loss by amniotic fluid (AF) contamination, AF was gathered in another suction. In the present study, massive bleeding was defined as blood loss of ≥2500 cc or requiring >3 units packed red blood

cells during the operation (12). Other morbidities, such as hysterectomy and admission duration, were documented. In the present study, accreta was classified as type 1 accreta and increta and percreta were classified as type 2 accreta, being more invasive based on pathologic reports (13).

The primary outcome was the relationship between the Doppler findings and massive bleeding. The secondary outcome was the relationship of the Doppler findings with the need for a hysterectomy, type of accreta, and other surgical morbidities, such as bladder and ureteral injury, intensive care unit admission, relaparotomy, and readmission.

Ethical statement

In implementing all stages of the study, privacy protection and confidentiality of the information obtained from files and other processes were considered. To preserve the pregnant women's information and the researchers blinding to the participants, a code was assigned to each pregnant woman, and used in all stages of registration. Data and analyses were performed using these codes.

Statistical analysis

All data were analyzed using SPSS, version 22 (IBM Inc., Armonk, NY, USA). A p-value less than 0.05 was considered significant. Mean ± standard deviation, median (minimum-maximum) were obtained for quantitative data. Also, frequency and relative frequency were obtained for qualitative data. The Kolmogorov-Smirnov test was used to assess normality of data distribution. All quantitative variables in this study had non-normal distribution. Therefore, Mann-Whitney test was used to investigate the relationship between quantitative variables and massive bleeding, hysterectomy, and pathology outcomes. The chi-square test was used to investigate the relationship between groups and categories for qualitative variables. Finally, receiver operating characteristic (ROC) curve was performed for variables and showed their specificities and sensitivities as prognostic parameters for PAS.

Results

Fifty-one pregnant women were included (Figure 1) with a mean age of 35.4±4.1 years and 34.4±2.1 weeks gestation (median: 28.0) at sonography. Their mean body mass index was 28.3±3.5 kg/m^2 and their mean admission was 4.15±1.1 days. Three (5.9%) women had no previous C/S with only a history of myomectomy, 31 (60.8%) had previous elective C/S, and 17 (33.3%) had previous emergent C/S in the non-active phase of labor. None of them had emergent C/S in the active phase of labor. In addition, 8 (15.7%) had a previous history of abortion (Table 1).

Surgical complications included one with a ureter injury during the operation (percreta case with parametrial involvement that was repaired via surgery). In addition, one had hematuria after the surgery, controlled by cystoscopy and bleeding vessel coagulation in the bladder. There was no laparotomy requirement in the study.

Bleeding

Severe bleeding occurred in 17 (33.3%). The median bladder PSV associated with women with severe bleeding was 57

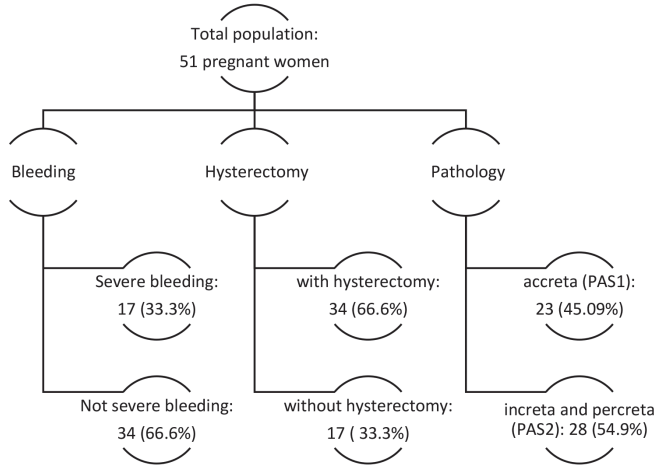

Figure 1. The flow chart of the population study
PAS: Placenta accreta spectrum

Table 1. The characteristic information of the pregnant women

Age (years)	35.4±4.11*; 35.00 (27, 48)**
Gestational age (weeks)	34.4±2.14*; 28.00 (18, 38)**
No previous C/S with only a history of myomectomy	3 (5.8%)***
History of emergent C/S	18 (35.29%)***
History of elective C/S	31 (60.78%)***
Previous surgery on the uterine	4 (7.84%)***
BMI (kg/m^2)****	28.33±3.53*; 27.75 (22, 39)**
Admission days (days)	4.15±1.12*; 4 (2, 14)**
History of abortion	8 (15.68%)***
Type of PAS***	
PAS1	23 (45.09%)***
PAS2	28 (54.9%)***
Hysterectomy after surgery	34 (66.66%)***
Severe blood loos	17 (33.33%)***

*: Mean ± standard deviation, **: Median (minimum, maximum), ***: Number (%), ****: Body mass index, *****: Accreta: PAS1, and increta and percreta: PAS2, BMI: Body mass index, PAS: Placenta accreta spectrum

(34-90) which was significantly greater (p<0.001) than in women without severe bleeding at 33 (20-64).

The median of cervical PSV among women with severe bleeding was 26 (0-63) while this was 18 (0-76) among women without severe bleeding (p=0.037). The median PSV of the left uterine artery in those with severe bleeding was 89 (81-135) which was again significantly greater than in those without severe bleeding at 68 (61-113; p=0.045).

The PSV of the higher vessels between the bladder and cervix was compared at the highest PSV value for each individual patient. The median of this PSV for women with severe bleeding was 57.5 (34-90) while it was 34 (20-76) for women without severe bleeding (p<0.001). All measures by Doppler US compared pregnant women with/without severe bleeding are demonstrated in Table 2. Also, Figure 2 shows the appearance of markers on Doppler US.

Hysterectomy

Hysterectomy was performed for 34 (66.7%) women. The median bladder PSV among women who had a hysterectomy was 46 (20-90), compared to 39.5 (33-46) among women who had not had a hysterectomy after their delivery (p=0.005). After delivery, women who had a hysterectomy demonstrated a cervical PSV of 20 (0-76) compared to 20 (14-26) among women without hysterectomy (p=0.013). The median PSV of the left uterine artery among pregnant women who had a hysterectomy after their delivery was 68 (61-135), while it was 82 (63-101) among pregnant women without hysterectomy (p=0.003).

The median PSV of the right uterine artery in pregnant women who underwent hysterectomy after delivery was 70 (51-125) while this was 82.5 (77-88) among pregnant women without hysterectomy (p=0.010).

The mean PSV of the two uterine arteries was calculated. The median of these mean PSVs in women who underwent hysterectomy was 71.5 (59-110) while it was 82.25 (70-94) among those who had not had a hysterectomy (p=0.001). Moreover, the median of the highest PSV measured in women who had a hysterectomy was 46 (20-90) compared to 39.5 (33-46) among women without hysterectomy (p=0.008). All measures by Doppler US compared pregnant women with/without hysterectomy are demonstrated in Table 3.

Histopathological assessment

All patients were confirmed to have PAS by histopathology. Subtype breakdown was 23 (45.1%) type 1 PAS and 28 (54.9%) type 2 PAS. Women with type 1 PAS had a median bladder PSV of 32 (20-64) while those with type 2 PAS had 46 (27-90) (p<0.001). The median cervical PSV in women with type 1 PAS was 18 (0-38), while it was 25 (0-76) for women with type 2 PAS (p=0.053). In type 1 PAS the median PSV of the left uterine artery was 68 (61-113) and the same parameter in type 2 PAS was 77 (61-135) (p=0.049). In type 1 PAS the median of the highest PSV was 32 (20-64) and this was 46 (27-90) in patients with type 2 PAS (p<0.001). All measures by Doppler US compared between pregnant women and the type of pathology are demonstrated in Table 4.

Table 2. The Doppler markers and blood loss among pregnant women

	Severe blood loss (≥2500 mL)	No severe blood loss (<2500 mL)	Total	p-value
Number (%)	17 (33.33%)	34 (66.66%)	51.00 (100%)	
Bladder PSV	57.0 (34, 90)	33.00 (20, 64)	41.00 (20.90)	<0.001
Cervix PSV	26.0 (0, 63)	18.00 (0, 76)	20.00 (0.76)	0.037
The largest lacuna PSV	0.00 (0, 23)	0.00 (0, 41)	0.00 (0.41)	0.56
The posterior lacuna of the bladder PSV	0.00 (0, 31)	0.00 (0, 35)	0.00 (0.35)	0.773
The left uterine artery PSV	89.00 (81, 135)	68.00 (61, 113)	72.00 (61, 136)	0.045
The right uterine artery PSV	75.00 (60, 110)	73.50 (51.7, 127.0)	74.00 (51.7, 127.0)	0.298
The mean uterine artery PSV	81 (60, 110)	71.25 (59, 107)	73.25 (59, 110)	0.093
The highest PSV	57.50 (34, 90)	34.00 (20, 76)	41.50 (20, 90)	<0.001
The left uterine artery PI	0.90 (0.60, 1.36)	0.77 (0.55, 1.77)	0.79 (0.55, 1.77)	0.453
The right uterine artery PI	0.91 (0.58, 76.00)	0.87 (0.54, 66.00)	0.89 (0.54, 76.00)	0.555
The mean PI of the uterine artery	0.91 (0.63, 38.45)	0.88 (0.55, 33.30)	0.89 (0.55, 38.45)	0.075
The left uterine artery RI	0.56 (0.39, 1.00)	0.49 (0.40, 0.75)	0.51 (0.39, 1.00)	0.222
The right uterine artery RI	0.53 (0.40, 0.66)	0.51 (0.40, 0.68)	0.51 (0.40, 0.68)	0.302
The mean RI of the uterine artery	0.53 (0.44, 0.74)	0.50 (0.41, 0.68)	0.41 (0.41, 0.74)	0.110
All data are demonstrated in median (minimum, maximum), PSV: Peak systolic velocity, PI: Pulsatility index, RI: Resistance index				

Receiver operating characteristic curve

In the ROC curve (Figure 3), the cut-off identified for bladder PSV was 41, with a sensitivity of 84% and specificity of 60% (p<0.001). Furthermore, the cut-off of cervical PSV was 18.5 with 84% sensitivity and 57% specificity (p<0.001). The cut-off associated with the highest PSV was 38.8, with 84% sensitivity and 60% specificity (p=0.033) (Table 5). However, the best cut-off for the mean PSV of the uterine arteries was 66.7, with 83% sensitivity and 15% specificity, which was not sufficiently distinctive (p=0.110).

Discussion

Evaluating methods and biomarkers, including laboratory values, US findings and measures, and demographic and clinical information, are being investigated to identify the optimal assessment protocol for diagnosis and prognosis of PAS. Chong et al. (14) reported an in-house US scoring was a suitable tool to predict the prognosis of the PAS, such as hysterectomy requirement and severe bleeding. Marsoosi et al. (15) suggested that the scoring system, including several simple ultrasound and clinical characteristics, could effectively predict the prognosis and severity of the PAS when combined with appropriate clinical judgment. The present study demonstrated that Doppler US measurements may be useful as biomarkers to clarify the severity of PAS.

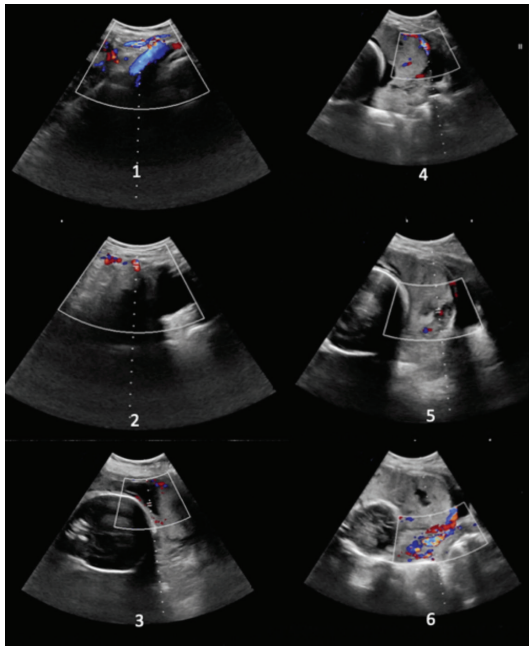

Figure 2. The Doppler sonography in pregnant women with placenta accreta spectrum. (1) The right uterine artery Doppler sonography, (2) The left uterine artery Doppler sonography, (3) The largest lacunae Doppler sonography, (4) The posterior of the bladder Doppler sonography, (5) The posterior lacunae Doppler sonography, (6) Cervix Doppler sonography

Table 3. The Doppler markers and hysterectomy among pregnant women

	Hysterectomy	No hysterectomy	p-value
Number (%)	34 (66.66)	17 (33.33)	
Bladder PSV	46.00 (20, 90)	39.50 (33, 46)	0.005
Cervix PSV	20.00 (0, 76)	20.00 (14, 26)	0.013
The largest lacuna PSV	0.00 (0, 18)	12.5 (0, 25)	0.835
The posterior lacuna of the bladder PSV	0.00 (0, 27)	0.00 (0, 0)	0.373
The left uterine artery PSV	68.00 (61, 135)	82.00 (63, 101)	0.003
The right uterine artery PSV	70.00 (51, 125)	82.50 (77, 88)	0.01
The mean uterine artery PSV	71.50 (59, 110)	82.25 (70, 94)	0.001
The highest PSV	46.00 (20, 90)	39.5 (33.46)	0.008
The left uterine artery PI	0.78 (0.51, 1.75)	1.18 (1.15, 1.22)	0.406
The right uterine artery PI	0.90 (0.54, 76.00)	0.72 (0.69, 0.76)	0.117
The mean PI of the uterine artery	0.89 (0.58, 38.45)	0.95 (0.95, 0.96)	0.374
The left uterine artery RI	0.50 (0.39, 1.00)	0.62 (0.62, 0.63)	0.147
The right uterine artery RI	0.50 (0.40, 0.66)	0.48 (0.47, 0.49)	0.96
The mean RI of the uterine artery	0.51 (0.44, 0.74)	0.55 (0.55, 0.55)	0.374
All data are demonstrated in median (minimum, maximum), PSV: Peak systolic velocity, PI: Pulsatility index, RI: Resistance index			

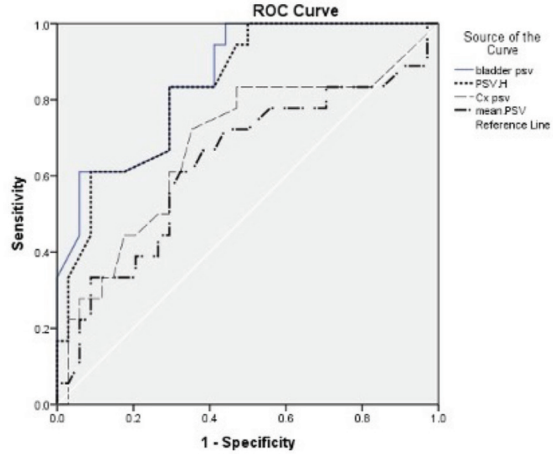

Figure 3. The receiver operating characteristic curve for bladder peak systolic velocity (PSV), cervix PSV, the highest PSV, and the mean PSV for diagnosis of placenta accreta spectrum

ROC: Receiver operating characteristic, PSV: Peak systolic velocity

Table 4. The Doppler markers and histopathology among pregnant women

	PAS 1 (accreta)	PAS 2 (increta and percreta)	p-value
Number (%)	23 (45.09%)	28 (54.91%)	
Bladder PSV	32.00 (20, 64)	46.00 (27, 90)	<0.001
Cervix PSV	18.00 (0, 38)	25.00 (0, 76)	0.053
The largest lacuna PSV	0.00 (0, 41)	0.00 (0, 25)	0.930
The posterior lacuna of the bladder PSV	0.00 (0, 37)	0.00 (0, 31)	0.373
The left uterine artery PSV	68.00 (61, 113)	72.00 (61, 135)	0.049
The right uterine artery PSV	70.00 (60, 125)	77.00 (51, 127)	0.273
The mean uterine artery PSV	71.00 (62, 107)	82.00 (59, 110)	0.111
The highest PSV	32.00 (20, 64)	46.00 (27, 90)	<0.001
The left uterine artery PI	0.77 (0.55, 1.77)	0.81 (0.57, 1.74)	0.220
The right uterine artery PI	0.90 (0.54, 66)	0.82 (0.54, 76)	0.289
Mean PI of the uterine artery	0.88 (0.55, 33.30)	0.91 (0.58, 38.45)	0.912
The left uterine artery RI	0.48 (0.40, 0.74)	0.51 (0.39, 1.00)	0.063
The right uterine artery RI	0.52 (0.40, 0.65)	0.50 (0.40, 0.68)	0.971
The mean RI of the uterine artery	0.50 (0.41, 0.68)	0.52 (0.44, 0.74)	0.153

All data are demonstrated in median (minimum, maximum), PAS: Placenta accreta spectrum, PSV: Peak systolic velocity, PI: Pulsatility index, RI: Resistance index

Table 5. The diagnostic ability of Doppler ultrasonography by ROC curve

Parameter	Cut-off	AUC*	p	Sensitivity	Specifity
Bladder PSV	41	0.885	<0.001	84%	60%
Cervix PSV	18.5	0.835	<0.001	84%	57%
Highest PSV	38.5	0.681	0.033	84%	60%
Mean PSV	66.7	0.636	0.110	83%	15%

*AUC: area under the curve, ROC: Receiver operating characteristic, PSV: Peak systolic velocity

Previously, some studies have suggested novel markers derived from Doppler US assessment to evaluate the prognosis of PAS. Al-Khan et al. (16) indicated that the presence of posterior urinary bladder wall pulsatile arterial vessels with low RI could be a suitable marker to predict the severity of the PAS. The present study investigated bladder PSV and showed that it was associated with severe bleeding, need for post-delivery hysterectomy, and invasive histopathology among pregnant women with PAS.

Yule et al. (17) showed that women confirmed with PAS who needed hysterectomy after the delivery reported an increase in color pixel area near the bladder-uterine serosal interface on transvaginal color Doppler US in the first trimester. The current study was not able to confirm these findings as all subjects were in the third trimester and we used trans-abdominal method. However, we found no significant relationship between the PSV of the posterior lacuna of the bladder and PAS outcomes.

Some studies have investigated the association between placenta accreta invasion and Doppler US findings. Hussein et al. (12) reported that markers described as "numerous coherent vessels involving the serosa-bladder interface" in 2D and 3D Doppler sonography were an independent marker to predict the severity and the complications facing pregnant women with PAS. Firmansha Dilmy et al. (18) showed that the flow index value in 3D Doppler sonography could predict the depth of the invasion in invasive PAS before surgery and the blood loss level. The present study showed that bladder PSV, the highest measured PSV, and the left uterine artery PSV were all significantly associated with invasive forms of PAS (increta and percreta).

In addition, the results of the present study showed that cervical PSV was associated with severe bleeding and a higher rate of hysterectomy among women with PAS. Cervical PSV may be a reasonably sensitive and specific marker to diagnose PAS among women with probable PAS, to enable better clinical decision making for their pregnancy and delivery. Of note in the present study, left uterine artery PSV emerged as a novel marker for diagnosis and predicting prognosis of PAS, which has not been reported previously.

In the present study only one expert prenatal fellow and the same two surgeons for cesarean section and hysterectomy if needed were used. This should minimize differences associated with larger teams of participating clinicians. Emergency deliveries were also excluded, so the blood loss due to the emergency situation was diminished. All pregnant women enrolled in the study were diagnosed with PAS with the appropriate criteria and this was confirmed histopathologically.

Study Limitations

This study has some limitations. The sample size was small and it was a single-center study. The high rate of hysterectomy among the patients was a potential source of bias and resulted from the higher rate of invasive and severe form of PAS among the pregnant women in our study, due to the center being a referral center. Moreover, using transvaginal US in

addition to transabdominal US and evaluating these markers in all trimesters among pregnant women separately could be appropriate in future research.

Conclusion

Bladder PSV, cervix PSV, and mean PSV between uterine arteries were confirmed as novel markers to predict the complications facing women with PAS, such as severe bleeding and hysterectomy. Also, these markers could predict the invasive forms of PAS (increta and percreta). Clinicians and surgeons may consider these markers derived from Doppler US as a non-invasive tool in the third trimester to help manage pregnant women with suspected PAS, with the aim of decreasing the morbidities and mortalities among them. However, further studies with a larger more general population are required to confirm these findings.

Ethics Committee Approval: *This study was approved by the Imam Khomeini Hospital Complex-Tehran University of Medical Sciences Local Ethics Committee (approval number: IR.TUMS.IKHC.REC.1400.201, date: 01.09.2021).*

Informed Consent: *Informed consent was obtained from all participants for inclusion in the study.*

Peer-review: *Externally peer-reviewed.*

Author Contributions: *Concept: M.S.; Design: M.S.; Materials: M.S.; Data Collection or Processing: F.G.V., A.S., S.M.G.A., Z.P., M.D.P., S.G.; Analysis or Interpretation: F.G.V., A.S., M.H.; Literature Search: F.G.V., A.S., S.H., S.B.; Writing: F.G.V., A.S., M.H.*

Conflict of Interest: *No conflict of interest is declared by the authors.*

Financial Disclosure: *The authors declared that this study received no financial support.*

References

1. D'Antonio F, Palacios-Jaraquemada J, Lim PS, Forlani F, Lanzone A, Timor-Tritsch I, et al. Counseling in fetal medicine: evidence-based answers to clinical questions on morbidly adherent placenta. Ultrasound Obstet Gynecol 2016; 47: 290-301.
2. Jauniaux E, Ayres-de-Campos D, Langhoff-Roos J, Fox KA, Collins S; FIGO Placenta Accreta Diagnosis and Management Expert Consensus Panel. FIGO classification for the clinical diagnosis of placenta accreta spectrum disorders. Int J Gynaecol Obstet 2019; 146: 20-4.
3. Timor-Tritsch IE, Monteagudo A. Unforeseen consequences of the increasing rate of cesarean deliveries: early placenta accreta and cesarean scar pregnancy. A review. Am J Obstet Gynecol 2012; 207: 14-29. doi: 10.1016/j.ajog.2012.03.007. Epub 2012 Mar 10. Erratum in: Am J Obstet Gynecol 2014; 210: 371-4.
4. El Gelany S, Mosbeh MH, Ibrahim EM, Mohammed M, Khalifa EM, Abdelhakium AK, et al. Placenta accreta spectrum (PAS) disorders: incidence, risk factors and outcomes of different management strategies in a tertiary referral hospital in Minia, Egypt: a prospective study. BMC Pregnancy Childbirth 2019; 19: 313.
5. Matsuzaki S, Mandelbaum RS, Sangara RN, McCarthy LE, Vestal NL, Klar M, et al. Trends, characteristics, and outcomes of placenta accreta spectrum: a national study in the United States. Am J Obstet Gynecol 2021; 225: 534.e1-38.
6. Piñas Carrillo A, Chandraharan E. Placenta accreta spectrum: Risk factors, diagnosis and management with special reference to the triple P procedure. Womens Health (Lond) 2019; 15: 1745506519878081.
7. Lerner JP, Deane S, Timor-Tritsch IE. Characterization of placenta accreta using transvaginal sonography and color Doppler imaging. Ultrasound Obstet Gynecol 1995; 5: 198-201.
8. Levine D, Hulka CA, Ludmir J, Li W, Edelman RR. Placenta accreta: evaluation with color Doppler US, power Doppler US, and MR imaging. Radiology 1997; 205: 773-6.
9. Shainker SA, Coleman B, Timor-Tritsch IE, Bhide A, Bromley B, Cahill AG, et al. Society for Maternal-Fetal Medicine. Electronic address: pubs@smfm.org. Special Report of the Society for Maternal-Fetal Medicine Placenta Accreta Spectrum Ultrasound Marker Task Force: Consensus on definition of markers and approach to the ultrasound examination in pregnancies at risk for placenta accreta spectrum. Am J Obstet Gynecol 2021; 224: B2-14.
10. Alfirevic Z, Stampalija T, Medley N. Fetal and umbilical Doppler ultrasound in normal pregnancy. Cochrane Database Syst Rev 2015; 2015: CD001450.
11. Collins SL, Stevenson GN, Al-Khan A, Illsley NP, Impey L, Pappas L, et al. Three-dimensional power Doppler Ultrasonography for diagnosing abnormally invasive placenta and quantifying the risk. Obstet Gynecol 2015; 126: 645-53.
12. Hussein AM, Momtaz M, Elsheikhah A, Abdelbar A, Kamel A. The role of ultrasound in prediction of intra-operative blood loss in cases of placenta accreta spectrum disorders. Arch Gynecol Obstet 2020; 302: 1143-50.
13. Hussein AM, Kamel A, Raslan A, Dakhly DMR, Abdelhafeez A, Nabil M, et al. Modified cesarean hysterectomy technique for management of cases of placenta increta and percreta at a tertiary referral hospital in Egypt. Arch Gynecol Obstet 2019; 299: 695-702.
14. Chong Y, Zhang A, Wang Y, Chen Y, Zhao Y. An ultrasonic scoring system to predict the prognosis of placenta accreta: A prospective cohort study. Medicine (Baltimore) 2018; 97: e12111.
15. Marsoosi V, Ghotbizadeh F, Hashemi N, Molaei B. Development of a scoring system for prediction of placenta accreta and determine the accuracy of its results. J Matern Fetal Neonatal Med 2020; 33: 1824-30.
16. Al-Khan A, Alshowaikh K, Krishnamoorthy K, Saber S, Alvarez M, Pappas L, et al. Pulsatile vessel at the posterior bladder wall: A new sonographic marker for placenta percreta. J Obstet Gynaecol Res 2022; 48: 1149-56.
17. Yule CS, Lewis MA, Do QN, Xi Y, Happe SK, Spong CY, et al. Transvaginal color mapping ultrasound in the first trimester predicts placenta accreta spectrum: a retrospective cohort study. J Ultrasound Med 2021; 40: 2735-43.
18. Firmansha Dilmy MA, Purwosunu Y, Saroyo YB, Hellyanti T, Wibowo N, Prasmusinto D, et al. Relationship of placental vascular indices with macroscopic, histopathologic, and intraoperative blood loss in placenta accreta spectrum disorders. Obstet Gynecol Int 2022; 2022: 2830066.