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ORIGINAL ARTICLE

The Diagnostic accuracy of Ultrasound and Color Doppler Imaging in predicting Placenta Accreta Spectrum

Eman Ahmed Ali[1*], Ibrahim Abdelaziz Libda[1], Mohammed Abd Alkhalik Basha[1], Enas Moustafa Ibrahim[1]

[1] Radiodiagnosis Department, Faculty of Medicine, Zagazig University, Egypt.

**** Corresponding author:***
Eman Ahmed Ali

Email:
emanamer2626@gmail.com

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ABSTRACT

Background: Placenta accreta spectrum (PAS) is a significant contributor to maternal mortality and morbidity. This disorder occurs when the placenta abnormally attaches to the uterus. The worldwide increase in cesarean sections (CS) has led to a rise in its prevalence. Timely diagnosis is crucial as it enables effective patient counseling, enhances the quality of care through multidisciplinary management for the mother and fetus, and optimizes the conditions for a successful cesarean delivery. We aimed to evaluate the accuracy of ultrasound (US) and color Doppler imaging in predicting PAS.

Method: In this prospective study, 60 pregnant women with placenta previa (after 28 weeks) who were at high risk of placenta accreta took part. An imaging study involving grayscale US and Doppler was conducted over a period of nine months. With operative data as a reference standard, US and Doppler imaging were evaluated for their diagnostic accuracy in predicting PAS.

Results: A statistically significant correlation has been observed between PAS and the quantity of prior CS. The association between PAS and age, gestational age, gravida, parity, abortion, or comorbidities is statistically not significant. The relationship between all placental bulges and bridging vessels and the presence of PAS is statistically non-significant. The most accurate US findings to diagnose PAS is the abnormal lacunae followed by loss of clear zone. Regarding Doppler findings, vascular clusters are the most accurate, followed by fetal artery traversing.

Conclusion: The US and color Doppler performed well in predicting PAS.

Keywords: Maternal mortality; Cesarean section; Placenta accreta; ultrasound.

INTRODUCTION

The term "placenta accreta spectrum" (PAS), formerly known as "morbidly adherent placenta," describes the pathological adherence of the placenta caused by isolated or diffuse aberrant trophoblastic invasion into the myometrium **[1].** Placenta accreta refers to the attachment of the placenta to the myometrium without the decidua in between; placenta increta is the invasion through the myometrium; and placenta percreta is the invasion through the serosa and subsequently other nearby structures **[2].** The rising rate of cesarean deliveries (CDs), a recognized risk factor for PAS, is associated with this rising rate. Placenta previa and prior CD are the two main risk factors for PAS. Asherman syndrome, high parity, previous uterine operations or curettage, and advanced maternal age are additional risk factors **[3].** High maternal morbidity from severe potentially fatal bleeding that necessitates blood transfusions and extra surgical procedures, such as a hysterectomy performed during delivery or in the postpartum phase, is linked to PAS. Longer hospital stays and an increased number of intensive care unit (ICU) admissions are linked to PAS **[4].**

It is essential to diagnose PAS during pregnancy to maximize maternal outcomes and schedule delivery at a level III or IV maternal care center **[5].** The introduction of ultrasound (US) and magnetic resonance imaging (MRI) made it possible to diagnose PAS in utero **[6].** While the majority of women receive a diagnosis in the

second or third trimester, US signs of PAS can be observed as early as the first trimester **[4].**

The US plays a crucial role in the diagnosis of PAS. Through high-resolution imaging, the US can detect signs of PAS, such as placental lacunae, loss of the retroplacental clear space, and abnormal placental vascularity. Additionally, the US can assess the depth of placental invasion into the myometrium and identify associated findings like placental bulge or heterogeneous myometrial involvement. Doppler US can further evaluate abnormal uteroplacental blood flow patterns, which are indicative of PAS. The early and accurate diagnosis of PAS by the US is crucial for proper management and planning of delivery, potentially reducing maternal morbidity and mortality **[7, 8]**.

This study aimed to identify intra-placental blood flow patterns and assess the predictive power of each sonographic parameter for PAS.

METHODS

Study type and population.

A prospective study was conducted at a tertiary hospital, involving 60 pregnant women with placenta previa (after 28 weeks) and a high risk of coexisting placenta accreta. The study spanned nine months, from July 2023 to March 2024. The patients were referred from our institution's obstetrics and gynecology department to the radiodiagnosis department. Following the Helsinki Declaration of the World Medical Association, this study was conducted. Approval was obtained from the institutional review board (ZU-10743, approved on April 30, 2023), and written informed consent was obtained from all participants. Specific inclusion and exclusion criteria were applied to enroll patients in the study. The inclusion criteria included gestational ages greater than 28 weeks, hemodynamic stability during the US examination, previous CS or history of uterine perforation, previous myomectomy, and informed consent. Patients who refused enrollment or were hemodynamically unstable during the US examination were excluded. All patients underwent clinical and radiological assessment.

Clinical assessment

A complete history-taking procedure was performed on each patient. This procedure involved gathering information such as their name, age, gravidity, parity, number of Cesarean sections, medical history, antepartum hemorrhage, previous history of uterine surgery, and the date of their most recent menstruation. Additionally, a comprehensive clinical assessment was conducted for every patient.

Radiological assessment

Ultrasound examination was conducted using a transabdominal and/or transvaginal approach with the Logic P7 ultrasound machine. Prior to the examination, pregnant women were prepared and reassured about its simplicity and benefits. During the abdominal examination, the pregnant women were instructed to have a semi-full urinary bladder. The routine obstetric ultrasound included confirming the gestational age and checking for the presence of placenta previa or low-lying placenta. To screen the placental tissue systematically, gray-scale B mode transabdominal sonography was used. Additionally, the ultrasound was used to assess the possibility of concomitant placenta accreta. The sonographic findings associated with placenta accreta include loss of a normal hypoechoic retroplacental zone, multiple vascular lacunae within the placenta giving it a "Swiss cheese" appearance, retroplacental myometrial thickness of 1 mm, bladder wall interruption, and presence of a placental bulge.

The color Doppler was utilized to assess both maternal and fetal blood flow patterns within the placenta. Attention was given to intraplacental clusters of vessels, lacunae, blood vessels, or placental tissue bridging the uterine-placental margin, myometrial-bladder interface, or crossing the uterine serosa. Utero-vesical hypervascularity, traversing vessels, and venous lakes were also assessed. To assess flow characteristics, velocities, and resistive indices of intraplacental vessels, spectral Doppler tracings were obtained. Furthermore, adjacent structures that may be invaded by placenta percreta were assessed.

Gold standard reference

The results were correlated with the operative data, as all patients underwent a cesarean section. This included information on whether the placenta separated spontaneously or not, the state of the placenta (such as focal accreta, total accreta, or previa), and the management approach (cesarean section or hysterectomy).

STATISTICAL ANALYSIS

The statistical package for the social sciences, or SPSS, version 26, was used to analyze the data. The Kolmogorov-Smirnov test, t-test for independent samples, Mann-Whitney test, chi-square test, and Monte Carlo tests were employed. To calculate the screening test's validity, cross-tabulation was employed. True positive/ (True positive+ False positive)*100 equals sensitivity. True negative / (True negative + False negative)*100 equals specificity. $P<0.05$ was chosen as the level of statistical significance. If p

≤0.001, a highly significant difference was detected.

RESULTS

The final analysis enrolled 60 patients (mean age, 30.12 years; age range, 21-39 years). The range of their gestational age, comorbidities, symptoms, and obstetric history was 30 weeks, 6 days to 37 weeks, and 3 days, respectively. A statistically significant correlation has been observed between PAS and the quantity of prior cesarean section (CS) (P<0.001). The association between the placenta accreta spectrum (PAS) and age, gestational age, gravida, parity, abortion, or comorbidities is statistically non-significant **(Table 1)**.

A statistically significant relationship was found between the presence of PAS and all of the following conditions: abnormal lacunae (95.3%), myometrial thinning (87.8%), uterovesical hypervascularity (86.4%), bladder wall interruption (all of them had PAS), and loss of clear zone (90.5%). The presence of PAS was shown to be statistically not significantly correlated with either bridging vessels (64.1%) or all placental bulges (68.7%). There is a statistically significant correlation between the presence of PAS and the following: low resistance maternal arterial waveform (<0.5) (91.9%), traversing fetal artery (92.7%), venous waveform (92.7%), fetal artery RI, and venous velocity is significantly higher among patients with PAS **(Table 2)**.

The study found that loss of clear zone can predict PAS with sensitivity of 88.4%, specificity of 76.5%, positive predictive value of 90.5%, negative predictive value of 72.2%, and overall accuracy of 85% when using ultrasonography data for PAS diagnosis among the patients. With a sensitivity of 95.3%, specificity of 70.6%, positive predictive value (PPV) of 89.1%, negative predictive value (NPV) of 85.7%, and overall accuracy of 88.3%, abnormal lacunae can predict PAS. With a sensitivity of 83.7%, specificity of 70.6%, PPV of 87.8%, NPV of 63.2%, and overall accuracy of 80%, myometrial thinning can predict PAS **(Table 3)**.

Predicting PAS with uterovesical hypervascularity has an overall accuracy of 81.7%, sensitivity of 88.4%, specificity of 64.7%, PPV of 86.4%, and NPV of 68.8%. With a sensitivity of 51.2%, specificity of 41.2%, PPV of 68.8%, NPV of 25%, and overall accuracy of 48.3%, placental bulge can predict PAS. With a sensitivity of 30.2%, specificity of 100%, PPV of 100%, NPV of 36.2%, and overall accuracy of 50%, bladder wall disruption can predict PAS. With a sensitivity of 58.1%, specificity of 17.6%, PPV of 64.1%, NPV of 14.3%, and overall accuracy of 46.7%, bridging vessels can predict PAS **(Table 3)**.

The vascular cluster can predict PAS with a sensitivity of 90.7%, specificity of 76.5%, PPV of 90.7%, NPV of 76.5%, and overall accuracy of 86.7%. Traversing fetal artery can predict PAS with a sensitivity of 88.4%, specificity of 82.4%, PPV of 92.7%, NPV of 73.7%, and overall accuracy of 86.7%. The venous waveform can predict PAS with a sensitivity of 83.7%, specificity of 88.2%, PPV of 94.7%, NPV of 68.2%, and overall accuracy of 85%. Low resistance maternal arterial waveform (RI <0.5) can predict PAS with a sensitivity of 79.1%, specificity of 82.4%, PPV of 91.9%, negative predictive value of 60.9%, and overall accuracy of 80% **(Table 3)**.

There is a statistically significant relation between the presence of PAS confirmed intraoperative and ultrasonography impression of PAS (83.7% of patients who were reported as having PAS by the US had confirmed PAS) **(Table 4)**.

Table (1): Relation between presence of placenta accreta spectrum (PAS) and baseline data of studied patients

	No PAS (n=17)	PAS (n=43)	t	p
	Mean ± SD	Mean ± SD		
Age (year)	30.86 ± 4.37	28.29 ± 4.66	2.002	0.05
Gestational age (week)	35.58 ± 1.34	35.7 ± 1.51	-0.304	0.762
	Median (IQR)	Median (IQR)	Z	p
Gravida	5(3 – 6)	4(3 – 6)	-1.315	0.188
Parity	3(2 – 4)	3(2 – 3)	-0.988	0.323
Abortion	1(0 – 1)	0(0 – 1)	-1.401	0.161
Number of previous cesarean sections (CS)	3(2 – 4)	2(2 – 3)	-2.153	0.031*
Comorbidities Absent	14 (28.6%)	35 (71.4%)	χ^2	

Diabetes Gestational diabetes Gestational hypertension	0 (0%) 3 (37.5%) 0 (0%)	1 (100%) 5 (62.5%) 2 (100%)	MC	0.733

Z Mann Whitney test t independent sample t test MC Monte Carlo test χ^2Chi square test

Table (2): Relation between presence of PAS and ultrasonography data of studied patients

Ultrasonography data	**No PAS** **N=17**	**PAS** **N=43**	**p**
Loss of clear zone Absent Present	 13 (72.2%) 4 (9.5%)	 5 (27.8%) 38 (90.5%)	<0.001**
Abnormal lacunae Absent Present	 12 (85.7%) 5 (4.7%)	 2 (14.3%) 41 (95.3%)	<0.001**
Myometrium thinning Absent Present	 12 (63.2%) 5 (12.2%)	 7 (36.8%) 36 (87.8%)	<0.001**
Uterovesical hyper vascularity Absent Present	 11 (68.8%) 6 (13.6%)	 5 (31.3%) 38 (86.4%)	<0.001**
Placental bulge Absent Present	 7 (25%) 10 (31.3%)	 21 (75%) 22 (68.7%)	0.592
Bladder wall interruption Absent Present	 17 (36.2%) 0 (0%)	 30 (63.8%) 13 (100%)	0.01*
Bridging vessels Absent Present	 3 (14.3%) 14 (35.9%)	 18 (85.7%) 25 (64.1%)	0.076
Vascular cluster Absent Present	 13 (76.5%) 4 (9.3%)	 4 (23.5%) 39 (90.7%)	<0.001**
Traversing fetal artery Absent Present	 14 (73.7%) 3 (7.3%)	 5 (26.3%) 38 (92.7%)	0.001**
Venous waveform Absent Present	 15 (68.2%) 2 (5.3%)	 7 (31.8%) 36 (94.7%)	0.001**
Low resistance maternal arterial waveform (resistive index(RI)<0.5) Absent Present	 14 (60.9%) 3 (8.1%)	 9 (39.1%) 34 (91.9%)	<0.001**
	Mean ± SD	**Mean ± SD**	**p**
Fetal RI	0.537 ± 0.038	0.453 ± 0.035	<0.001**
Venous velocity (cm/sec)	12.712 ± 1.33	10.212 ± 1.046	<0.001**

Table (3): Performance of ultrasonography findings in diagnosis of PAS among studied patients

	Sensitivity	Specificity	PPV	NPV	Accuracy
Loss of clear zone	88.4%	76.5%	90.5%	72.2%	85%
Abnormal lacunae	95.3%	70.6%	89.1%	85.7%	88.3%
Myometrium thinning	83.7%	70.6%	87.8%	63.2%	80%
Uterovesical hyper vascularity	88.4%	64.7%	86.4%	68.8%	81.7%
Placental bulge	51.2%	41.2%	68.8%	25%	48.3%
Bladder wall interruption	30.2%	100%	100%	36.2%	50%
Bridging vessels	58.1%	17.6%	64.1%	14.3%	46.7%
Vascular cluster	90.7%	76.5%	90.7%	76.5%	86.7%
Traversing fetal artery	88.4%	82.4%	92.7%	73.7%	86.7%
Venous waveform	83.7%	88.2%	94.7%	68.2%	85%
Low resistance maternal arterial waveform (RI <0.5)	79.1%	82.4%	91.9%	60.9%	80%

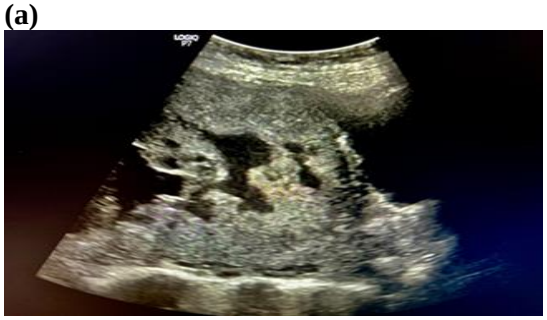
PPV positive predictive value NPV negative predictive value

Table (4): Relation between presence of confirmed intraoperative PAS and overall ultrasound impression of studied patients:

Ultrasonography	No PAS N=17	PAS N=43	p
PAS			
Absent	9 (81.8%)	2 (18.2%)	<0.001**
Present	8 (16.3%)	41 (83.7%)	

**p≤0.001 is statistically highly significant χ^2 Chi square test

(a)



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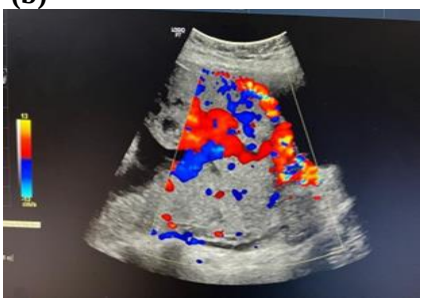

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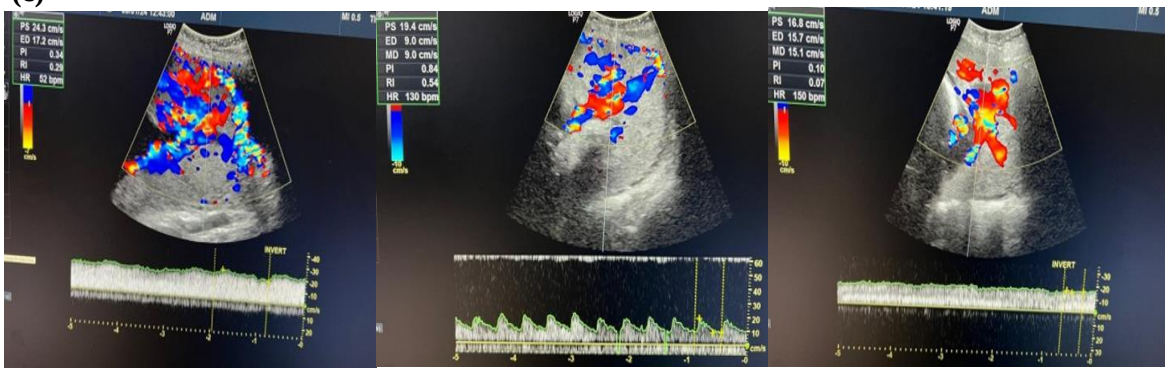

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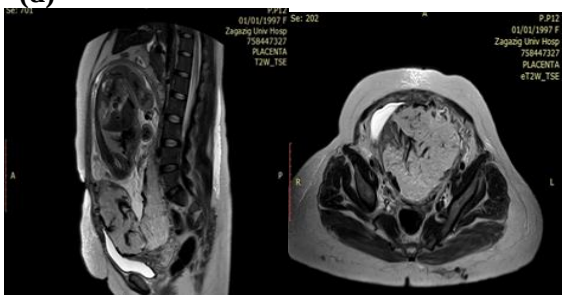

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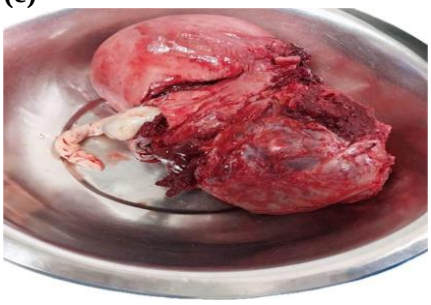

Figure (1): 34 Years old female G4P3 with history of two CS, presented with vaginal bleeding. Us and color Doppler with performed at 34 weeks ; (a) Gray scale findings shows irregular placental lacunae not compressed after the prope compression, myometrium thinning <1 mm, loss of retro placental hyoechoic space, bladder wall interruption with placental bulge into the bladder**; (b)** Doppler findings shows marked increased vascularity with turbulent flow intraplacental vascular clusters, uterovesical hyper vascularity, bridging vessels, with traversing fetal artery that transverse placental width**; (c)** Pulsed Doppler shows wave form within the intraplacental vascular clusters: high velocity venous wave form (PSV=16,8 cm/s), low resistance maternal arterial wave form (HR=52 bpm), and fetal arterial wave form (HR= 130 bpm); (d) MRI shows 1-sagittal T2WI : heterogeneous lumpy placenta with thick dark bands and prominent intraplacental vessels, myomertial thinning at anterior lower uterine segment, placenta appear tethered and invades anterior abdominal wall at site of previous scar. Axial T2WI show the placenta extend through to uterine serosa resulting in disruption of the myometrium signal**; (e)** hysterectomy specimen shows the uterus after the hysterectomy with the placenta in situ**.**

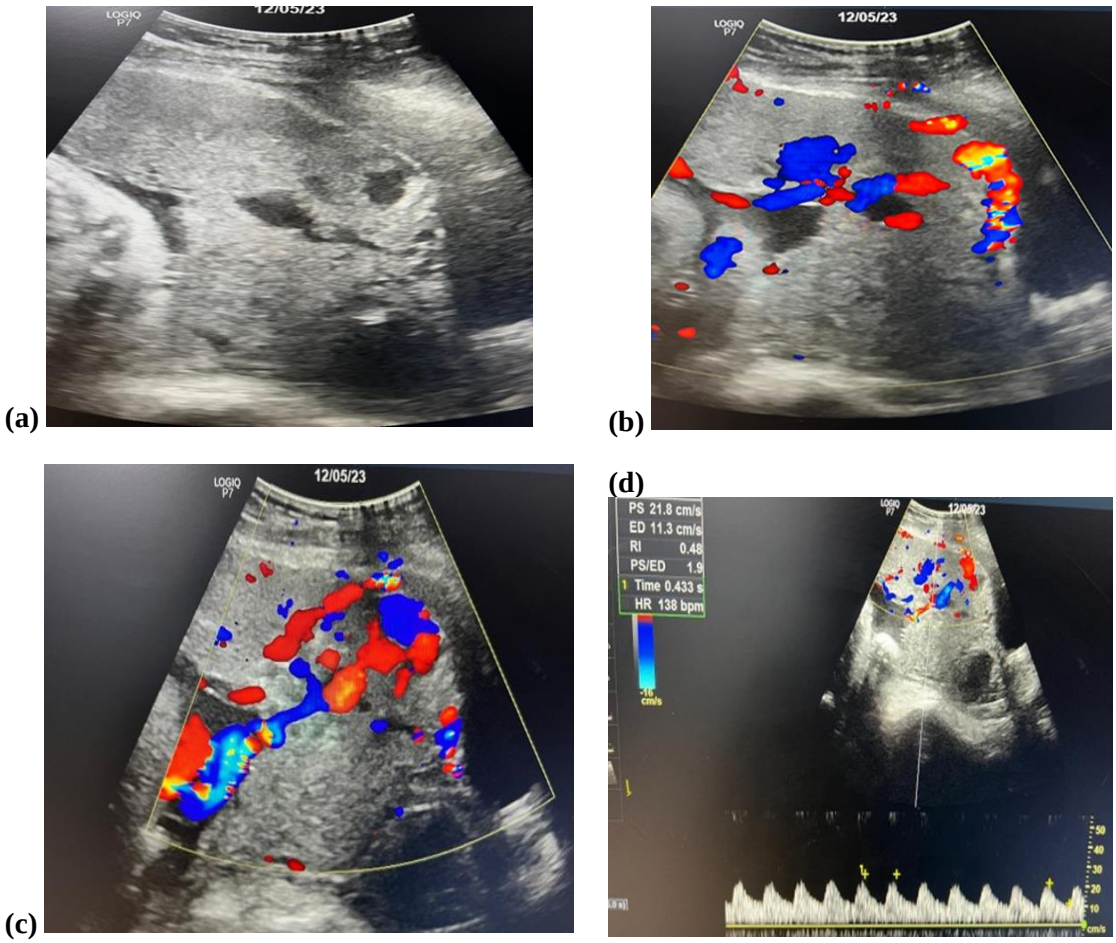

Figure (2): 31 Years old female G3P2 with DM, history of two CS, presented with vaginal bleeding.us and color Doppler was performed at 35 weeks (a) Gray scale findings shows irregular placental lacunae not compressed after the prope compression, myometrium thinning <1 mm, loss of retro placental hyoechoic space, bladder wall interruption and placental bulge into the bladder. Doppler findings show (b) increased vascularity with turbulent flow lacunae, utrovesical hyper vascularity with bridging), (c) with traversing fetal artery that transverse placental width, (d) with pulsed Doppler (HR= 138 pbm).

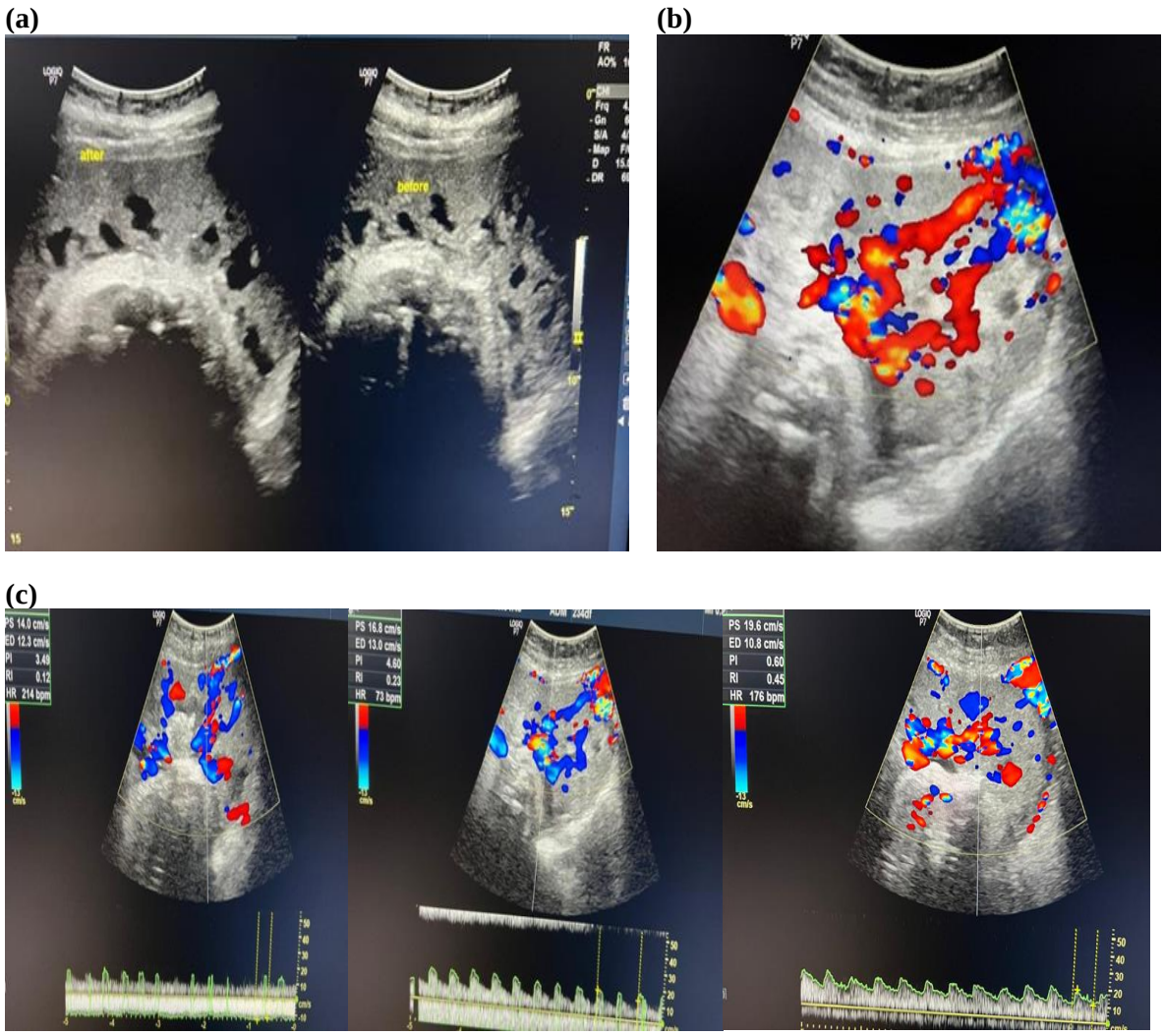

Figure (3): 31 Years old female G4P3 with history of three CS, presented with vaginal bleeding.us and color Doppler was performed at 34 weeks. Trans abdominal US of Placenta low lying on anterior wall: (a) Gray scale findings shows irregular placental lacunae not compressed after the prope compression, myometrium thinning <1 mm, loss of retro placental hypoechoic space ; **(b)** Doppler findings shows increased vascularity with turbulent flow intraplacental vascular clusters, uterovesical hyper vascularity , bridging vessels , with traversing fetal artery that transverse placental width; (c) Pulsed Doppler shows Three types of Wave forms within the intraplacental vascular clusters:, high velocity venous wave form (psv=14cm/s), low resistance maternal arterial wave form (HR=73 bpm), fetal arterial wave form (HR= 176 bpm).

DISCUSSION

The present study analyzed color and spectral Doppler ultrasound findings in 60 women with low-lying anterior placentas or placenta previa to evaluate the diagnostic performance for the placenta accreta spectrum (PAS). The mean age was 30.12 years, and the gestational age ranged from 30 weeks, 6 days to 37 weeks, 3 days. Our results showed no statistically significant association between PAS and maternal age or gestational age, consistent with previous studies by **Eid (10)** and **Kliewer et al. (11)**. However, **Elmaraghy et al. (12)** reported a significant relationship between PAS and older maternal age, which could be attributed to differences in sample size or inclusion criteria.

Regarding obstetric history, the median gravidity, parity, and abortion were 4, 3, and 0, respectively. The number of previous cesarean sections (CS) ranged from 1 to 5, with a median of 2. Our study found a statistically significant association between PAS and the number of prior CS, which aligns with the findings of **Kliewer et al. (11)**. However, **Eid (10)** did not observe a significant association between PAS and the number of previous CS, potentially due to differences in the study population or methodology.

In terms of comorbidities, 13.3% of patients had gestational diabetes, 3.3% had gestational

hypertension, and 1.7% had diabetes mellitus. Our study demonstrated no statistically significant relationship between PAS and comorbidities, consistent with the findings of **Romeo et al. (13)** and **Givens et al. (14)**.

US examination revealed that 93.3% of patients in our study had complete central placenta previa. Loss of the clear zone, abnormal lacunae, myometrial thinning, uterovesical hypervascularity, vascular cluster, placental bulge, bladder wall interruption, bridging vessels, and traversing fetal artery were detected in 70%, 76.7%, 68.3%, 73.3%, 71.7%, 53.3%, 21.7%, 65%, and 68.3% of cases, respectively. The overall ultrasound impression reported PAS in 81.7% of patients. Our results showed a statistically significant association between PAS and the presence of loss of clear zone (90.5%), abnormal lacunae (95.3%), myometrial thinning (87.8%), uterovesical hypervascularity (86.4%), and bladder wall interruption (100%). However, no significant correlation was found between PAS and placental bulge (68.7%) or bridging vessels (64.1%). These findings are consistent with previous studies by **Eid (10)** and **Romeo et al. (13)**.

Regarding management, 50% of patients underwent transverse lower cesarean section (TLCS), and 38.3% underwent cesarean hysterectomy. In contrast, **Elmaraghy et al. (12)** and **Gulati et al. (15)** reported higher rates of cesarean hysterectomy for PAS cases (85% and 84.2%, respectively). The management approach may vary depending on the severity of placental invasion and institutional protocols.

In terms of maternal outcomes, 83.3% of patients in our study had good outcomes without requiring intensive care unit (ICU) admission. However, **Gulati et al. (15)** reported one maternal death (5.3%) among PAS patients, highlighting the potential risks associated with this condition. Early detection and appropriate management of PAS are crucial in reducing maternal morbidity and mortality.

Receiver operating characteristic (ROC) curve analysis demonstrated that abnormal lacunae had the best diagnostic accuracy for PAS (sensitivity of 95.3%, specificity of 70.6%, positive predictive value (PPV) of 89.1%, negative predictive value (NPV) of 85.7%, overall accuracy of 88.3%), followed by loss of clear zone (sensitivity of 88.4%, specificity of 76.5%, PPV of 90.5%, NPV of 72.2%, accuracy of 85%). These findings align with the study by **Eid (10)**, further emphasizing the diagnostic utility of these US features.

Regarding Doppler US findings, our study revealed a statistically significant association between PAS and the presence of vascular cluster (90.7%), traversing fetal artery (92.7%), venous waveform (94.7%), low resistance maternal arterial waveform (resistance index (RI) <0.5) (91.9%), and higher fetal artery RI and venous velocity. These results are consistent with previous studies by **Kliewer et al. (11)** and **Shabana et al. (16)**, highlighting the value of Doppler ultrasound in diagnosing PAS.

ROC curve analysis showed that the vascular cluster had the best diagnostic performance for PAS (sensitivity 90.7%, specificity 76.5%, PPV 90.7%, NPV 76.5%, accuracy 86.7%), followed by traversing fetal artery (sensitivity 88.4%, specificity 82.4%, PPV 92.7%, NPV 73.7%, accuracy 86.7%). These findings align with **Kliewer et al. (11)** and **Shabana et al. (16)**, further emphasizing the diagnostic utility of these Doppler features.

Notably, our study revealed that a fetal artery RI ≥ 0.485 could predict PAS with an AUC of 0.956, sensitivity of 93%, specificity of 82.4%, PPV of 93%, NPV of 82.4%, and overall accuracy of 90%. Additionally, a venous velocity ≥ 11.65 cm/second could predict PAS with an AUC of 0.92, sensitivity of 86%, specificity of 94.1%, PPV of 94.7%, NPV of 72.7%, and overall accuracy of 88.3%. To our knowledge, this is the first study to investigate the diagnostic accuracy of fetal artery RI and venous velocity in the identification of PAS, and our larger sample size adds strength to these findings.

Our study demonstrated a statistically significant relationship between the presence of PAS confirmed intraoperatively and the ultrasound impression of PAS (83.7% of patients reported as having PAS by ultrasound had confirmed PAS). This finding is consistent with previous studies by **Eid (10)** and **Borg et al. (17)**, further emphasizing the reliability of ultrasound in diagnosing PAS.

Regarding the overall diagnostic performance of ultrasound for PAS, our study revealed a sensitivity of 95.3%, specificity of 52.9%, PPV of 83.7%, NPV of 81.8%, and overall accuracy of 83.3%. These results are comparable to the findings of **Borg et al. (17)** and **Amine et al. (18)**, highlighting the value of ultrasound as a diagnostic tool for PAS.

The study had some limitations, including a small sample size, single-center design, operator dependency in US and Doppler examinations, a limited follow-up period, and potential confounding factors that were not accounted for. Future multicenter studies with larger sample sizes and longer follow-up periods are warranted to address these limitations and further validate

the diagnostic performance of ultrasound and Doppler findings in PAS.

Conclusion

The study highlights the vital role of US and color Doppler imaging in accurately predicting PAS, facilitating timely management, and improving maternal outcomes. Specific markers, including abnormal placental lacunae, loss of clear zone, vascular clusters, and abnormal Doppler indices, demonstrated high diagnostic value. Future multi-center studies with larger sample sizes and longer follow-up periods are warranted to validate our findings and further investigate the risk factors associated with PAS.

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