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Accuracy of three-dimensional multislice view Doppler in diagnosis of placenta accreta spectrum

Amira Elnahas **GadElrab** [1], Wessam Magdy AbdELaziz **AboElghar** [1], Khaled Hassan **Swedan** [1], Eman AbdElSalam **NasrElDin** [2,*], Ahmed **ElShahawy** [1]

[1] Department of Obstetrics and Gynecology, Faculty of Medicine, Ain Shams University, Cairo, Egypt.
[2] Department of Radiodiagnosis, Faculty of Medicine, Helwan University, Cairo, Egypt.

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***Corresponding author:** Eman AbdElSalam **NasrElDin**, M.D., Lecturer in Radiodiagnosis. Department of Radiodiagnosis, Faculty of Medicine, Helwan University, Helwan, Cairo, Egypt.
Email: dremansalam77@gmail.com.
ORCID: 0000-0001-6993-5603.

ABSTRACT

Objective. To evaluate the accuracy of three-dimensional multislice view Doppler as a diagnostic tool in the diagnosis of placenta accreta spectrum.
Materials and Methods. Seventy eight pregnant women with persistent placenta previa totalis (after 28 weeks' gestation) were prospectively enrolled into this study. Gray-scale transabdominal ultrasound examination was performed to detect loss of the subendometrial echolucent zone and other abnormalities suggestive of placental invasion. Three-dimensional multislice view Doppler was used to scan the whole placenta to detect any vessels invading the uterine serosa-bladder interface or presence of abnormal lacunae. Ultrasound findings were analyzed with reference to histopathological results.
Results. Placenta accreta and its variants (increta and percreta) were confirmed in 39 women by pathological results. Diagnostic value of three-dimensional multislice view Doppler using 2 or more criteria of placental invasion showed a sensitivity of 87%, specificity of 96%, and accuracy of 91% (area under ROC curve [AUC] = 0.961). Disruption of the uterine serosa-bladder interface was the best single criterion for the diagnosis of placenta accreta (sensitivity = 95% and specificity = 96%).
Conclusions. Three-dimensional multislice view Doppler can be used as an accurate test for diagnosis of placenta accreta spectrum.

INTRODUCTION

Placenta accreta spectrum (PAS) has become a life-threatening issue, its incidence is increasing significantly with marked morbidity and mortality. The markedly increased rate of caesarean section and increased maternal age explain this upsetting increase in PAS [1]. PAS refers to different degrees of invasion of the uterine wall and/or its surrounding (placenta accreta, increta and percreta) [2]. Accurate antenatal diagnosis of PAS allows proper assessment and management by experienced multidisciplinary teams in tertiary referral centers, thus improving maternal outcome [3].
Current prenatal diagnosis depends on the interpretation of ultrasound findings using two-dimensional

(2D) grey-scale and color Doppler imaging. Many signs are reported in literature with varying degrees of sensitivity and specificity [4]. Several consensus statements have been published by experts aiming to standardize the description and allow appropriate comparison of imaging signs for diagnosis of PAS [5, 6]. Magnetic resonance imaging (MRI), although has proved a beneficial role in the diagnosis of PAS, yet did not show significant improvement in pregnancy outcome or management [7]. MRI is expensive and unavailable in most low and medium-income countries, hence it is only recommended as adjunct to ultrasound in certain cases [8].

This study investigates the value of three-dimensional multislice view (3D MSV) Doppler as a single adiagnostic tool in the diagnosis of PAS and compare its diagnostic performance based on receiver–operating characteristics (ROC) curve analysis.

MATERIALS AND METHODS

This prospective observational study was conducted at Ain Shams University Hospital, Cairo, Egypt, during the period from December 2019 to September 2021. Approval of the Obstetrics and Gynecology Department's Ethical Committee was obtained before commencement of the study (N = FWA000017585). 78 pregnant women diagnosed after 28 weeks' gestation with persistent low lying anterior placenta covering the scar of previous caesarean section were enrolled in the study. Placenta previa was diagnosed using 2-dimentional (2D) ultrasound (SAMSUNG MEDISON CO, LTD, Korea MODEL WS80A) with 4-7 MHz convex probe. An informed written consent was obtained from all women before enrollment in the study after explaining the aim and risks of the study.

2D gray-scale ultrasound and 3DMSV Doppler were performed for all women with sufficient urinary bladder volume to clearly visualize the serosa–bladder interface, and the angle of insonation was kept as low as possible. Criteria used to diagnose morbidly adherent placenta using the 2D gray-scale ultrasound were; Loss of the retro placental sonolucent zone (interruption of interface between the posterior bladder wall and the uterus) (**Figure 1**), irregular retro-placental sonolucent zone, thinning or disruption of hyperechoic serosa-bladder interface, presence of focal exophytic masses invading the urinary bladder (mass with same echogenicity as the placenta beyond the uterine serosa), and abnormal placental lacunae (irregular vascular spaces in the placental parenchyma) (**Figure 1**) [9].

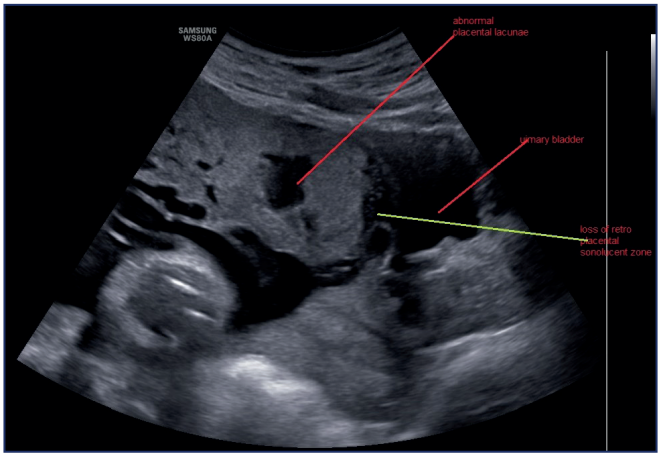

Figure 1. *2D gray-scale ultrasound showing loss of retro-placental sonolucent zone and abnormal placental lacunae.*

3D power Doppler examination was targeted to the region of the lower uterine segment and the placenta. Three to five 3D volumes were obtained in automatic sweeps using a motorized curved array transducer while the women held their breath. In order to interpret the data consistently, the settings of power were adjusted at 100% and pulse repetition frequency at 0.9 kHz for all examinations. Offline image analysis was performed using either the ultrasound platform or a PC-based program. Ultrasound examination was performed using a 3DMSV ultrasound system equipped with a 4-8 MHz transabdominal transducer (the WS80A with Elite features with Crystal Clear Cycle). During the 3DMSV Doppler technique, the 3D volume transducer was mechanically and systematically moved over the defined region of interest (ROI) to obtain volume data in three planes (sagittal, coronal, and axial). Sampling was performed between 95 and 255 consecutive slices per volume. The volume data were stored on the machine's hard drive. Slices were generated either from the initial plane or any other reconstructed ROI. The most informative image among the multiple slices was displayed with the use of Medison Dynamic MR, a post-processing tool that allowed one to reduce speckle artifacts, leading to sharper depiction of the tissue margins. Image processing was performed through the use of off-line software (Medison XI Viewer, version v1.1.0.723). Immediately after image acquisition was completed, the volume images were displayed on the monitor in a multislice view either for sagittal or coronal or axial planes. In addition, the volumes of a defined cube were manipulated to bring out a particular scan plane or reconstructed to a volume rendered image, and the general morphologic condition of

the vascular network within a ROI was obtained in power mode. The presence of at least one of the following criteria by 3DMSV doppler indicated placenta accreta (including its variants, placenta increta and placenta percreta): abnormal placental lacunae (**Figure 2**), disruption of the uterine serosa-bladder interface, numerous vessels invading the uterine serosa-bladder interface, or crowded vessels over the peripheral sub-placental zone (**Figures 3, 4**) [10].

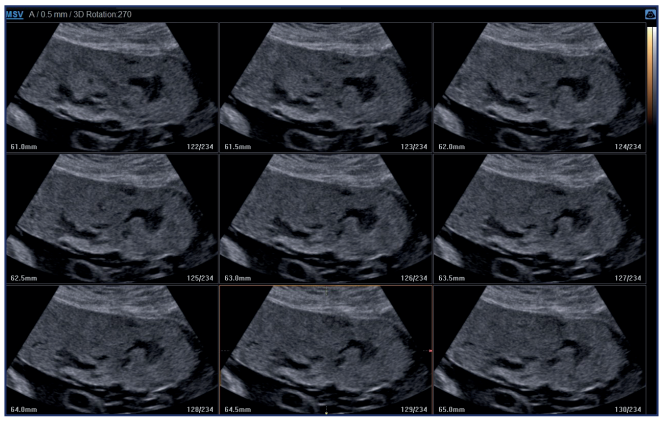

Figure 2. *3DMSV showing abnormal placental lacunae.*

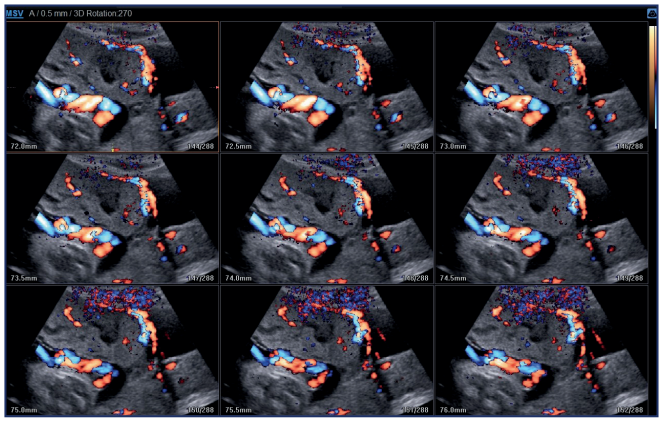

Figure 3. *Placenta accreta with 3DMSV showing abnormal placental lacunae, disruption of the uterine serosa-bladder interface, numerous vessels invading the uterine serosa-bladder interface, and crowded vessels over the peripheral sub-placental zone.*

According to the institutional protocol of management, women were delivered at completed 36 weeks, following adminstration of corticosteroids for fetal lung enhancement, or emergency cesarean section was performed if significant bleeding developed before the time of the planned delivery. Operative findings including difficulty of placental separation, and different degrees of placental invasion were recorded. Histopathological examination of the uterus was performed in cases managed by hysterectomy, while in those managed conservatively without hysterectomy, resection of part of the lower segment or curettage of the placental bed was done for histopathological examination when possible. Histopathology confirmed the diagnosis of PAS when placental villi where found anchored directly on, or invading into or through, the myometrium, without an intervening decidual plate. The placenta is characterized as accreta, increta, or percreta, depending on the greatest depth of myometrial invasion (superficial, deep, or penetrating the entire uterine wall). Histopathologic findings were compared with preoperative sonography findings to detect the accuracy of the 3DMSV Doppler to diagnose PAS .

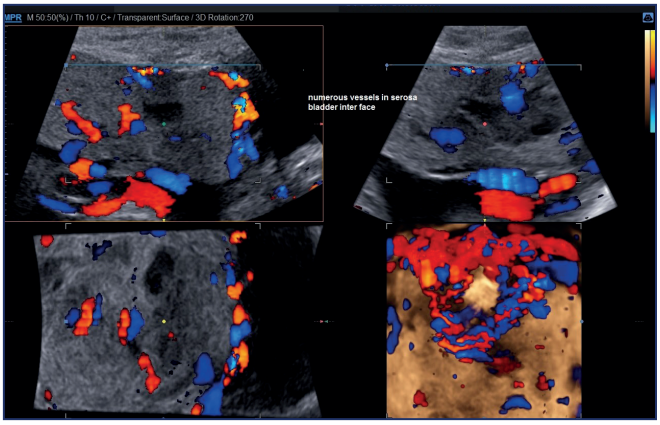

Figure 4. *3D power Doppler showing abnormal placental lacunae, disruption of the uterine serosa-bladder interface, numerous vessels invading the uterine serosa-bladder interface.*

Data were analyzed using IBM© SPSS© Statistics version 23 (IBM© Corp., Armonk, NY). Categorical variables were presented as counts or proportions and percentages. Diagnostic accuracy for individual sonographic criteria was assessed using cross-tabulation of each criterion versus histopathologic diagnosis as the gold-standard and calculating the true positive (TP), false positive (FP), true negative (TN), and false-negative (FN) rates. The following diagnostic indices were then calculated: sensitivity, specificity, positive and negative predictive values, positive and negative likelihood ratios, and correct classification and misclassification rates. Receiver-operating characteristic (ROC) curve analysis is used to identify the best cutoff number of sonographic criteria for diagnosis of placental invasion. The area under the ROC curve (AUC) is interpreted as follows:

- < 0.6 = fail;
- 0.6 to 0.69 = poor;
- 0.7 to 0.79 = fair;
- 0.8 to 0.89 = good;
- ≥ 0.9 = excellent.

RESULTS

During the 2 years period of the study, a total of 78 women diagnosed with low lying placenta were enrolled, base line charectiristics are shown in **Table 1**. Only 24 (30.8%) women were managed by cesarean hysterectomy, while 54 women were managed conservatively without hysterectomy. Histopathology was done only for 65 cases, where curreting of the placental bed was performed in 30 (38.5%) and part of the lower uterine segment was removed in 11 (14.1%) women while specimen were not obtained from 13 (16.7%) cases as the placenta was separated spontaneously without any signs of invasion. The histopathology proved the presence of PAS in 39/65 (60%) women and no placental invasion in the remaining 26/65 (40%) specimens. 2D gray scale ultrasound diagnosed diagnosed 38/78 (48.7%) women with at least on criteria suggesting PAS, while 3DMSV Doppler diagnosed 51/65 (65.4%) women (**Table 2**).

Receiver-operating characteristic (ROC) Curve for diagnosis of placental invasion using number of 2D gray scale US Criteria showed a poor diagnostic value (area under ROC curve [AUC] = 0.671) with best cutoff value is 2 or more criteria (sensitivity = 46%; specificity = 88%; J-index = 0.346; accuracy = 63%) (**Figure 5**). The presence of abnormal placental lacunae was the best single criterion for prediction of PAS (**Table 3**). Receiver-operating characteristic (ROC) Curve for diagnosis of placental invasion using number of 3DMSV Doppler criteria showed an excellent diagnostic value with area under ROC curve [AUC] = 0.961. Best cutoff is 2 or more criteria (sensitivity = 87%; specificity = 96%; J-index = 0.833; accuracy = 91%) (**Figure 6**). Disruption of the serosa bladder interface, visualized in the basal view of 3DMSV Doppler was the best single criterion for the diagnosis of PAS, with sensitivity of 95% and specificity of 96% (**Table 4**).

Table 1. *Base line characteristics of the women enrolled in the study.*

Characteristic		Mean ± SD or n (%)
Age (years)		29.6 ± 4.75
Parity	P_1	15 (19.2%)
	P_2	22 (28.2%)
	P_3	17 (21.8%)
	P_4	12 (15.4%)
	≥ P_5	12 (15.4%)
BMI (kg/m^2)		26.37 ± 4.93
Previous cesarean section (CS)	1 CS	19 (24.4%)
	2 CS	24 (30.8%)
	3 CS	20 (25.65)
	4 CS	8 (10.3%)
	5 CS	7 (9%)
Previous uterine curettage (D&C)	No	27 (34.6%)
	1 D&C	34 (43.6%)
	2 D&C	14 (17.9%)
	≥ 3 D&C	3 (3.9%)
Previous PAS		11 (14.1%)

Table 2. *Preoperative 2D gray scale ultrasound and 3DMSV Doppler diagnosis of PAS.*

2D gray scale ultrasound		
Characteristic		**N (%)**
Number of criteria for PAS	No	40/78 (51.3%)
	1 criteria	11/78 (14.1%)
	2 criterias	16/78 (20.5%)
	3 criterias	7/78 (9.0%)
	4 criterias	4/78 (5.1%)
Type of criteria for PAS	Abnormal placental lacunae	26/78 (33.3%)
	Disruption of serosa-bladder interface	20/78 (25.6%)
	Focal exophytic mass invading bladder	19/78 (24.4%)
	Loss of retro-placental sonolucent zone	15/78 (19.2%)
3DMSV Doppler		
Characteristic		**N (%)**
Number of criteria for PAS	No	27/78 (34.6%)
	1 criteria	10/78 (12.8%)
	2 criterias	9 /78 (11.5%)
	3 criterias	12/78 (15.4%)
	4 criterias	20/78 (25.6%)
Type of criteria for PAS	Abnormal placental lacunae	34/78 (43.6%)
	Disruption of serosa-bladder interface	44/78 (56.4%)
	Numerous coherent vessels invading serosa-bladder interface	32/78 (41.0%)
	Crowded vessels over peripheral sub-placental zone	34/78 (43.6%)

DISCUSSION

Antenatal diagnosis nof PAS can help to prevent several maternal mortalities and morbidities oweing to proper preoperative preparations [10], proper counseling for possible cesarean hysterectomy and other morbidities, referral to a well equipped tertiary center with available adequate blood products or cell-salvage technology, pre- and intra-operative preparations including anesthesia consul-

Table 3. *Diagnostic value of abnormal placental lacunae by 2D gray scale ultrasound.*

	Histopatholgy		
2D GSUS	**Histopathology (+ ve)**	**Histopathology (- ve)**	**Total**
Criterion (+ ve)	17	3	20
Criterion (- ve)	22	23	45
Total	39	26	65
Statistics	**Value**	**Lower bound (95%)**	**Upper bound (95%)**
Correct classification	62%	50%	73%
Misclassification	38%	27%	50%
Sensitivity	44%	29%	59%
Specificity	88%	70%	97%
False positive rate	12%	0%	23%
False negative rate	56%	42%	71%
Prevalence	60%	48%	72%
Positive predictive value	85%	69%	100%
Negative predictive value	51%	37%	66%
Positive likelihood ratio	3.78	1.23	11.61
Negative likelihood ratio	0.64	0.47	0.87
Relative risk	1.74	1.23	2.45
Odds ratio	5.92	1.64	21.41

Table 4. *Diagnostic value of disruption of serosa-bladder interface by 3DMSV Doppler.*

	Histopatholgy		
3DMSV Doppler	**Histopathology (+ ve)**	**Histopathology (- ve)**	**Total**
Criterion (+ ve)	37	1	38
Criterion (- ve)	2	25	27
Total	39	26	65
Statistics	**Value**	**Lower bound (95%)**	**Upper bound (95%)**
Correct classification	95%	90%	100%
Misclassification	5%	0%	10%
Sensitivity	95%	82%	99%
Specificity	96%	79%	100%
False positive rate	4%	0%	11%
False negative rate	5%	0%	12%
Prevalence	60%	48%	72%
Positive predictive value	97%	92%	100%
Negative predictive value	93%	83%	100%
Positive likelihood ratio	24.67	3.60	168.80
Negative likelihood ratio	0.05	0.01	0.21
Relative risk	13.14	4.03	42.91
Odds ratio	462.50	57.44	3723.67

tation, ureteric stenting, and balloon occlusion of hypogastric vessels might be beneficial [11, 12]. The surgical outcome and degree of hemorrhage in PAS is mainly dependent on the degree of placental invasion, uteroplacental vascularity, and placental invasion of adjacent structures as urinary bladder [13]. Thus, proper antenatal diagnosis enabeling proper preparation and timing of intervention, is crucial in the management of PAS.

Second and third trimester 2D gray scale ultrasound has been used for long as the main diagnostic tool for PAS mainly due to its availability, 2D Doppler have been used also in conjunction though has not proved to increase the diagnostic accuracy substantially [14]. Several signs were suggested and studied for the diagnosis of PAS with variable degrees of sensitivity and specificity, the most widely accepted are the loss or irregularity of the retro placental sonolucent zone, thinning or disruption of hyperechoic serosa-bladder interface, presence of focal exophytic masses invading the urinary bladder, and presence of abnormal pla-

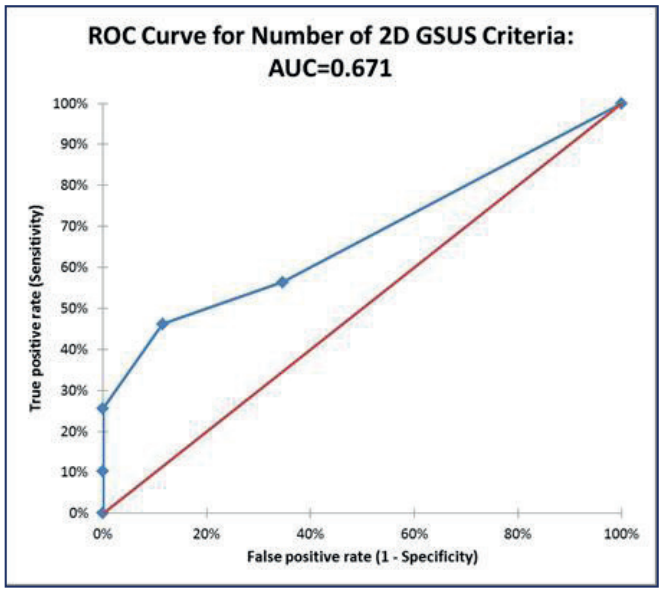

Figure 5. *Receiver-operating characteristic (ROC) Curve for diagnosis of placental invasion using number of 2D gray scale US Criteria.*

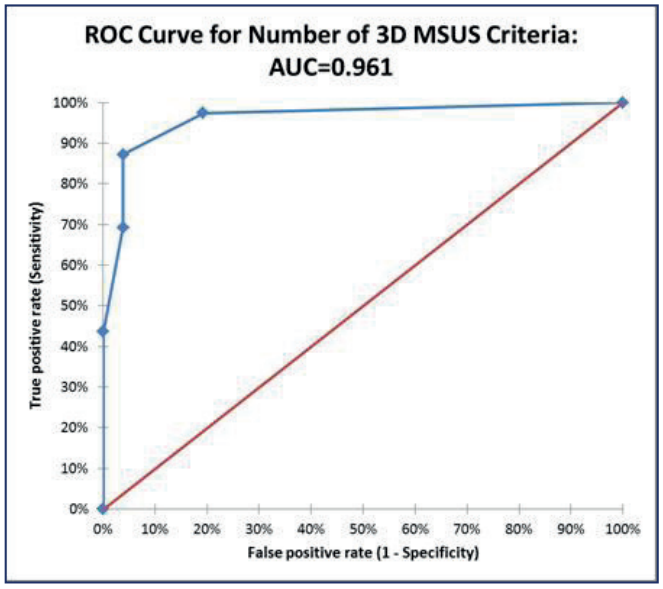

Figure 6. *Receiver-operating characteristic (ROC) Curve for diagnosis of placental invasion using number of 3DMSV Doppler criteria.*

cental lacunae [9]. Still, this study has found low diagnostic accuracy for the use of these criteria, sensitivity 46% and specificity 88% of a cutoff value of 2 or more criteria with the best diagnostic accuracy of presence of abnormal placental lacunae (sensitivity 44% and specificity 88%). Other studies showed better specificity for these signs but still with less than desirable sensitivity [10, 15, 16].

Magnetic resonance imaging (MRI) was introduced as a diagnostic modality for detection of PAS, still, due to its cost and unavailability, MRI use is mainly reserved when sonographic findings are inconclusive [17], some even failed to find a significant difference in its diagnostic accuracy, sensitivity, and specificity compared to sonography [18]. Owing to the importance and clinical significance of antenatal diagnosis of PAS, the search continues for a more accurate and feasible diagnostic modality. In the recent years, 3D ultrasound and Doppler have been studied as a useful diagnostic modality for many obstetric conditions one of which is PAS. In recent years, a new technique, 3DMSV was introduced for the diagnosis of some uterine and fetal anomalies but its value in the diagnosis of PAS was not well studied [19-21]. 3DMSV comprises both an oblique view mode and a multislice view mode, it allows sequential slice scans of a scanned 3D volume with an adjustable slice interval according to the volume size and ROI to obtain the best plane for analysis [21]. Similar to MRI and computed tomography, it allows to display several slices on one screen, thus, a slice-by-slice approach obtains a better choice of the most informative image to attain an accurate diagnosis. Thus, instead of depending on the operator skill who performs this process mentally during 2D ultrasound, 3DMSV provides a more subjective diagnostic tool [19].

The study used the same diagnostic criteria decribed by the ordinary 3D power Doppler for the evaluation of 3DMSV Doppler [10]. The current study suggests that 3DMSV Doppler might become a very valuable tool for the antenatal diagnosis of PAS, the best criterion suggested was the disruption of the hyperechoic serosa-bladder interface with sensitivity 95%, specificity 96%, and positive predictive value 97%. This technique has the advantage of being less operator dependent than ordinary 2D or 3D ultrasound, and the multislice images can be revised by other operators. Another case control study suggested that 3DMSV Doppler had a better diagnostic accuracy compared to 2D gray scale ultrasound and 3D power Doppler for the prediction of difficult placental separation and considerable intraoperative blood loss with the presence of crowded vessels over the peripheral sub-placental zone showing best sensitivity (82.6%) [22]. The current study compares the ultrasound findings to the postoperative histopathological findings rather than observational intraoperative findings. Still, this study being a diagnostic accuracy test, more trials are needed to validate the usefulness of this modality and its impact on clinical practice and obstetric outcome.

CONCLUSIONS

This study suggest that 3D MSVDoppler is a valuable diagnostic modality for PAS.

COMPLIANCE WITH ETHICAL STANDARDS

Authors contribution

A.E.G.: Clinical participation, collection of data, writing the manuscript, funding. W.M.A.A.: Study design, clinical participation, supervision of study, funding. K.H.S.: Study design, supervision of study, funding. E.A.N.: Clinical participation, collection of data, writing the manuscript, funding. A.E.: Study design, clinical participation, collection of data, funding.

Funding

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Study registration

The study was not registered as it is not a clinical trial.

Disclosure of interests

The authors declare that they have no conflict of interests.

Ethical approval

Approval of the Obstetrics and Gynecology Department's Ehical Committee was obtained before commencement of the study (N = FWA000017585).

Informed consent

An informed written consent was obtained from all women before enrollment in the study after explaining the aim and risks of the study.

Data sharing

The authors confirm that the data supporting the findings of this study are available within the article [and/or] its supplementary material. The data that support the findings of this study are available on request from the corresponding author.

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