# Accuracy of three-dimensional multislice view Doppler in diagnosis of morbid adherent placenta

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## Abstract

**Objective:** To detect the accuracy of the three-dimensional multislice view (3D MSV) Doppler in the diagnosis of morbid adherent placenta (MAP).

**Material and Methods:** Fifty pregnant women at  $\geq$ 28 weeks gestation with suspected MAP were included in this prospective study. Two dimensional (2D) trans-abdominal gray-scale ultrasound scan was performed for the subjects to confirm the gestational age, placental location, and findings suggestive of MAP, followed by the 3D power Doppler and then the 3D MSV Doppler to confirm the diagnosis of MAP. Intraoperative findings and histopathology results of removed uteri in cases managed by emergency hysterectomy were compared with preoperative sono-graphic findings to detect the accuracy of the 3D MSV Doppler in the diagnosis of MAP.

**Results:** The 3D MSV Doppler increased the accuracy and predictive values of the diagnostic criteria of MAP compared with the 3D power Doppler. The sensitivity and negative predictive value (NPV) (79.6% and 82.2%, respectively) of crowded vessels over the peripheral sub-placental zone to detect difficult placental separation and considerable intraoperative blood loss in cases of MAP using the 3D power Doppler was increased to 82.6% and 84%, respectively, using the 3D MSV Doppler. In addition, the sensitivity, specificity, and positive predictive value (PPV) (90.9%, 68.8%, and 47%, respectively) of the disruption of the uterine serosa-bladder interface for the detection of emergency hysterectomy in cases of MAP using the 3D power Doppler was increased to 100%, 71.8%, and 50%, respectively, using the 3D MSV Doppler.

**Conclusion:** The 3D MSV Doppler is a useful adjunctive tool to the 3D power Doppler or color Doppler to refine the diagnosis of MAP. (J Turk Ger Gynecol Assoc 2015; 16: 126-36)

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## Introduction

Placenta accreta occurs when placental trophoblasts invade the endometrium beyond the Nitabuch's layer of decidua basalis, placenta increta occurs when placental trophoblasts invade the myometrium, and placenta percreta occurs when placental trophoblasts invade the serosa (1, 2).

Morbid adherent placenta (MAP) is generally associated with excess blood loss, bladder injuries and hysterectomies (3, 4). The incidence of MAP has increased significantly over the last 50 years (5, 6).

A past history of a cesarean delivery, placenta previa, and damage of the Nitabuch's layer of decidua basalis following intrauterine infection or scarring are the risk factors of MAP. The incidence of MAP is increased concomitantly with increased cesarean section rates (1, 7-9).

The incidence of MAP is 3.3% in pregnant women with no past history of cesarean delivery and placenta previa and is 40% in pregnant women with a history of two cesarean

sections and placenta previa (4). If MAP was diagnosed or suspected before delivery, the optimum time for planned delivery is around 34–35 weeks, following a course of corticosteroids and multidisciplinary team care approach (2, 10, 11). An accurate diagnosis of MAP is essential to prepare both the patient and health providers for possible complications during delivery. Authors reported that ultrasound is a useful tool to diagnose MAP, with 77%–93% sensitivity and 71%–98% specificity (12-16).

Moodley et al. (17) concluded that the color flow Doppler was more specific, with a 95% negative predictive value (NPV) in the prenatal diagnosis of MAP, than magnetic resonance imaging (MRI), and MRI should be reserved for cases with inconclusive sonographic findings (13, 15, 17). The sonographic markers of placenta accreta can be seen in the first trimester of pregnancy in the form of low implantation of the pregnancy sac and multiple vascular spaces within the placenta (2).

Prenatal diagnosis of MAP with gray-scale and Doppler sonography allows the development of the multidisciplinary team care approach during delivery (14). This current study aimed



to evaluate the accuracy of the three-dimensional multislice view (3D MSV) Doppler in the diagnosis of MAP.

### **Material and Methods**

From February 2010 to February 2012, pregnant women at  $\geq$ 28 weeks gestation with placenta previa anterior covering the scar of the previous cesarean section scar by trans-abdominal gray-scale ultrasound scan were included in the current study after the approval of the ethical committee. A thorough analysis of the history and examination of all the subjects was followed by two-dimensional (2D) trans-abdominal gray-scale ultrasound scan to confirm the gestational age, placental location, and findings suggestive of MAP. The findings suggestive of MAP by 2D gray-scale ultrasound scan were as follows:

- 1. Obliteration of a clear space between the uterus and placenta (Figure 1, 2),
- 2. Visualization of the placental lacunae (irregular vascular spaces), moth-eaten appearance of the placenta (Figure 1, 2),
- 3. Interruption of the posterior uterine serosa-bladder interface, and
- 4. Exophytic mass invading the bladder (11, 18).

The 2D gray-scale ultrasound scan was first performed followed by the 3D power Doppler and then the 3D MSV Doppler by a sonographer who was blinded to the patient's criteria to confirm the diagnosis of MAP. All scans were performed for all subjects in the supine position, with sufficient bladder volume to allow the optimal visualization of the uterine serosa-bladder interface using the Medison machine (Sonoace X8, Medison Co., South Korea) with a 4–7 MHz (Megahertz) multi-frequency convex probe. The 3D power Doppler was targeted to analyze and define the vasculature of the lower uterine segment and placenta. Using a motorized curved array transducer with 100% power, 0.9 KHz of pulse repetition frequency, -5.4 gain, and low wall motion filter, 3-5 3D volumes were obtained. The 3D power Doppler images were analyzed using a computerized program. Two views of the 3D power Doppler were generally analyzed; lateral view to observe the intra-placental vasculature and basal view to observe the serosa-bladder interface. At least one of following findings was suggestive of MAP by the 3D power Doppler:

- Disruption of the retro-placental sonolucent zone and/or abnormal placental lacunae in lateral view,
- 2. Numerous vessels invading the uterine serosa-bladder interface and/or crowded vessels over the peripheral subplacental zone in basal view (Figure 3).

During the 3D MSV 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. MSV allows a simultaneous display of multiple parallel cuts per volume, up to 24 preselected parallel cuts (slices) from a volume (19, 20). Slices can be generated either from the initial or any other reconstructed ROI. In addition, vasculature within a defined ROI was obtained in power mode (19, 20). The most informative image from parallel cuts (slices) was displayed using Medison



Figure 1. 2D gray scale ultrasound scan shows the loss of the retro-placental sonolucent zone and abnormal placental lacunae in MAP



Figure 2. 2D gray scale ultrasound scan shows the loss of the retro-placental sonolucent zone and abnormal placental lacunae in MAP

Dynamic-like Magnetic Resonance (DMR), a post-processing tool to reduce speckle artifacts, leading to sharp images. Image processing was performed using Medison XI Viewer, version v1.1.0.723 software. Findings of the 3D MSV Doppler suggestive of MAP were as follows:

1. Abnormal placental lacunae (Figure 4a, b) arrow A, 2. Disruption of the uterine serosa-bladder interface (Figure 4b, c) arrow B, 3. Numerous vessels invading the uterine serosa-bladder interface (Figure 4 d-f) arrow C, and 4. Crowded vessels over the peripheral sub-placental zone (19, 20).

According to the hospital protocol, subjects were hospitalized at 32 weeks and delivered at 35 weeks, following a course of corticosteroids. An emergency cesarean section was performed if significant bleeding developed before the time of the planned cesarean section. All deliveries were conducted in the



Figure 3. 3D power Doppler shows numerous vessels invading the serosa-bladder interface, disruption of the retro-placental sonolucent zone, and abnormal placental lacunae

presence of obstetrics and anesthetic consultants on duty, and the urologist on duty was informed in case bladder injury or reconstruction was needed (2-10). A written consent explaining the possible intraoperative complications (blood transfusion, hysterectomy, internal iliac ligation) and postoperative complications (deep venous thrombosis, prolonged hospital stay, and intensive care unit admission) was obtained from all subjects. Women included in this study were also cross-matched with fresh frozen plasma and packed red blood cells (RBCs). Intraoperative findings, including a difficulty in placental separation, degree of placental invasion, bleeding from the placental site, amount of blood loss, intraoperative blood transfusion, need for internal iliac ligation or emergency hysterectomy to control the bleeding, and histopathology results of the removed uteri in cases managed by emergency hysterectomy specialists were recorded (21). The calculated estimated blood loss (cEBL) was evaluated using the formula proposed by Stafford et al. (22). Intraoperative findings (Figure 5) were compared with preoperative sonography findings to detect the accuracy of the 3D MSV Doppler to diagnose MAP.

#### Sample size justification

Using data from previous studies which found; a strong association between bladder invasion in MAP and 3D power Doppler findings (23), color Doppler had 82.4% sensitivity, 96.8% specificity, 87.5% and 95.3% positive and negative predictive values; respectively to diagnose MAP (12) and Epilnfo® version 6.0 a sample size of 49 women was needed to produce a significant difference after assuming a 5% drop-out rate.

#### Statistical analysis

Data were collected and statistically analyzed using the Statistical Package for Social Sciences (SPSS) computer software version 18 (SPSS Inc., Chicago, Illinois, USA). Mean and standard deviation (SD) were used to represent numerical variables, while number and percentage were used to represent categorical variables. Student's t and Mann–Whitney's U tests



Figure 4. 3D MSV Doppler; (a) and (b) shows abnormal placental lacunae (arrow A); (b) and (c) shows disruption of the uterine -bladder interface (arrow B); (d), (e), and (f) shows numerous vessels invading the uterine serosa-bladder interface (arrow C)



Figure 5. Intraoperative findings of a case of MAP with numerous engorged vessels over the uterine serosa and confirmed as placenta percreta after hysterectomy

were used for the analysis of quantitative data, chi-square test for the analysis of qualitative data, Spearman's correlation test to detect the relationship between quantitative variables, and regression analysis to predict the outcome of categorical dependent variables. A p value <0.05 was considered significant. In addition, the sensitivity, specificity, and predictive values of the ultrasound diagnostic criteria of MAP were calculated.

### Results

Demographic data of 50 subjects with suspected MAP are presented in Table 1. Of the total subject population, 56% (28/50) had difficult placental separation, considerable blood loss ( $\geq$ 1500 cc), and received blood transfusion. Bilateral internal iliac artery ligation was performed to control bleeding in 28% (14/50) of subjects, intrauterine compression balloon with

Variables	Total number of studied women=50
Age (years)	31.22±4.82*
Duration from last cesarean section (years)	3.4±2.39*
Gestational age at scan (weeks)	30.6±3.17*
Gestational age at delivery (weeks)	34.7±1.2*
Preoperative hematocrit	30.8±3.3*
48-h postoperative hematocrit	27.3±4.1*
Postoperative hematocrit drop	3.4±2.4*
Considerable intraoperative blood loss ( $\geq$ 1500 cc)	28 (56%) **
Intraoperative blood transfusion	28 (56%)**
Easy placental separation	22 (44%)**
Difficult placental separation	28 (56%)**
No need for additional surgical steps	22 (44%)**
Bilateral Internal Iliac Ligation	14 (28%)**
Emergency hysterectomy	11 (22%)**
Intrauterine compression balloon and placental bed sutures	3 (6%)**
Histopathology results of surgically removed uteri	
Placenta accreta	5 (10%)**
Placenta increta	4 (8%)**
Placenta percreta	2 (4%)**
Intraoperative bladder injury	5 (10%)**
*Data represented as Mean±SD; **Data represented as Number and percentage	

Table 1.	Preoper	ative and	intraop	erative o	data of	subjects	with st	uspected	morbid	adherent	placenta
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Table 2. Women who had difficult placental delivery and considerable intraoperative blood loss compared with women who did not have difficult placental delivery or considerable blood loss

Variables	Women who had difficult placental delivery and considerable intraoperative blood loss (number=28)	Women who did not have difficult placental delivery or considerable intraoperative blood loss (number=22)	p significance
Age (years)	$30.3 \pm 5.2$	30.9±4.1	0.13* (NS)
Mean±SD			
Body mass index (BMI), (kg/m²)	25.3±3.2	24.7±2.9	0.32* (NS)
Mean±SD			
Parity	4 (1–6)	1 (1–2)	0.02** (S)
Median (Range)			
Number of previous cesarean section	3 (1–4)	1 (1–2)	0.04** (S)
Median (Range)			
Gestational age at delivery (weeks)	$35.9 \pm 1.7$	36.2±1.4	0.18* (NS)
Mean±SD			
*Analysis using independent student's t-test; NS: non-significant; S: significant	**Analysis using Mann–Whitney's U-test	t.	·

placenta bed sutures was performed in 6% (3/50) of subjects, and cesarean hysterectomy was performed in 22% (11/50) of subjects. Histopathological examination of surgically removed uteri showed placenta accreta in 10% (5/50) cases, placenta increta in 8% (4/50) cases, and placenta percreta in 4% (2/50) cases) cases. In total, 10% (5/50) cases of bladder injury were recorded during this study (Table 1).

The number of cesarean deliveries and parity were high among women who had difficult placental delivery, considerable intraoperative blood loss, and who required emergency hysterectomy to control bleeding (Table 2, 3).

Variables	Women who required emergency hysterectomy (number=11)	Women who did not require hysterectomy (number=39)	p significance
Age (years)	$30.8 \pm 4.8$	31.3±4.9	0.49* (NS)
Mean±SD			
Body mass index (BMI), (kg/m <sup>2</sup> )	25.2±2.1	24.4±3.9	0.97* (NS)
Mean±SD			
Parity	4 (2–4)	2 (1-4)	0.02** (S)
Median (Range)			
Number of previous cesarean section	3 (1-4)	1 (1–2)	0.02** (S)
Median (Range)			
Gestational age at delivery (weeks)	36.1±1.3	36.9±1.2	0.33* (NS)
Mean±SD			
*Analysis using independent student's t-test NS: non-significant; S: significant	**Analysis using Mann–Whitney's U-	test.	

Table 3. Women who required emergency hysterectomy to stop bleeding compared with women who did not require hysterectomy

Observations of the loss of the retro-placental sonolucent space, irregular retro-placental sonolucent area, disruption of the uterine serosa-bladder interface, and exophytic mass invading the bladder by 2D gray-scale ultrasound were significantly high in women who had difficult placental separation and considerable intraoperative blood loss compared with women who did not have difficult placental separation or considerable blood loss (92.8%, 89.3%, 64.3%, and 28.6% vs. 31.8%, 22.7%, 9.1%, and 0%, respectively). Observations of the disruption of the uterine serosa-bladder interface, numerous vessels invading the uterine serosa-bladder interface, and crowded vessels over the peripheral sub-placental zone by the 3D power Doppler were significantly high in women who had difficult placental separation and considerable intraoperative blood loss compared with women who did not have difficult placental separation or considerable blood loss (78.6%, 78.6%, and 89.3% vs. 27.3%, 27.3%, and 27.3%, respectively). Observations of the disruption of the hyperechoic serosa-bladder interface, numerous coherent vessels invading the serosa-bladder interface, and crowded vessels over the peripheral sub-placental zone by the 3D MSV Doppler were also significantly high in women who had difficult placental separation and considerable intraoperative blood loss compared with women who did not have difficult placental separation or considerable blood loss (85.7%, 89.3%, and 89.3%) vs. 9.1%, 9.1%, and 22.7%, respectively) (Table 4).

Observations of the loss of the retro-placental sonolucent space, irregular retro-placental sonolucent area, disruption of the uterine serosa-bladder interface, and exophytic mass invading the bladder by 2D gray-scale ultrasound were significantly high in women who required emergency hysterectomy (100%, 100%, 81.8%, and 36.4% vs. 33.3%, 30.8%, 17.9%, and 5.1%, respectively). Observations of the disruption of the uterine serosa-bladder interface, crowded vessels over the peripheral sub-placental zone, and abnormal placental lacunae by the 3D power Doppler were significantly high in women who required

emergency hysterectomy compared with women who did not require hysterectomy (90.9%, 90.9%, and 90.9% vs. 20.5%, 30.8%, and 28.2%, respectively). Observations of the disruption of the hyperechoic serosa-bladder interface, crowded vessels over the peripheral sub-placental zone, and abnormal placental lacunae by the 3D MSV Doppler were also significantly high in women who required emergency hysterectomy compared with women who did not require hysterectomy (100%, 100%, and 100% vs. 28.2%, 38.5%, and 35.9%, respectively) (Table 5).

All gray-scale, power Doppler, and 3D MSV Doppler findings, except abnormal placental lacunae, had a significant positive correlation with difficult placental separation, considerable intraoperative blood loss, and emergency hysterectomy using Spearman's rank correlation coefficient. The best 2D gray-scale ultrasound parameters for the detection of difficult placental separation and considerable intraoperative blood loss in the subjects were abnormal placental lacunae (73.9% sensitivity), exophytic mass invading the bladder (100% specificity and 100% PPV), and loss of the retro-placental sonolucent space (74.2% NPV). The best 3D power Doppler parameters for the detection of difficult placental separation and considerable intraoperative blood loss in the subjects were crowded vessels over the peripheral sub-placental zone (79.6% sensitivity and 82.2% NPV) and disruption of the uterine serosa-bladder interface (82.2% specificity and 79.7% PPV). In addition, the best 3D MSV Doppler parameters for the detection of difficult placental separation and considerable intraoperative blood loss in the subjects were crowded vessels over the peripheral sub-placental zone (82.6% sensitivity and 84% NPV) and disruption of the uterine hyperechoic serosa-bladder area (85.2% Specificity and 81.1% PPV) (Table 6).

The best 2D gray-scale ultrasound parameters for the detection of hysterectomy in the subjects with MAP were disruption of the uterine serosa-bladder interface (81.8% sensitivity) and exophytic mass invading the bladder (94.9% specificity, 66.7% PPV, and 84.1% NPV). The best 3D power Doppler parameters for the

### Table 4. 2D gray-scale, 3D power Doppler, and 3D MSV Doppler findings in women who had difficult placental separation and considerable intraoperative blood loss compared with women who did not have difficult placental separation or considerable intraoperative blood loss

Variables	Women who had difficult placenta separation and considerable intraoperative blood loss (number=28)	Women who did not have difficult placenta separation or considerable intraoperative blood loss (number=22)	p significance
2D gray-scale findings			
Loss of the retro-placental sonolucent space	26 (92.8%)	7 (31.8%)	0.03 (S)
Irregular retro-placental sonolucent area	25 (89.3%)	5 (22.7%)	0.01 (S)
Disruption of the uterine serosa-bladder interface	18 (64.3%)	2 (9.1%)	0.006 (S)
Exophytic mass invading the bladder	8 (28.6%)	0 (0%)	0.003 (S)
Abnormal placental lacunae	21 (75%)	14 (63.6%)	0.7 (NS)
3D power Doppler findings			
Disruption of the uterine serosa-bladder interface	22 (78.6%)	6 (27.3%)	0.02 (S)
Numerous vessels invading the serosa- bladder interface	22 (78.6%)	6 (27.3%)	0.02 (S)
Crowded vessels over the peripheral sub- placental zone	25 (89.3%)	6 (27.3%)	0.02 (S)
Abnormal placental lacunae	17 (65.7%)	15 (68.2%)	0.7 (NS)
3D MSV Doppler findings			
Disruption of the hyperechoic serosa-bladder interface	24 (85.7%)	2 (9.1%)	0.001 (S)
Numerous coherent vessels invading the serosa- bladder interface	25 (89.3%)	2 (9.1%)	0.001 (S)
Crowded vessels over the peripheral sub- placental zone	25 (89.3%)	5 (22.7%)	0.01 (S)
Abnormal placental lacunae	17 (65.7%)	14 (63.6%)	0.1 (NS)
Data represented as number and percentage; Analysis us	sing chi-square (X <sup>2</sup> ) test.	, , , ,	

NS: non-significant; S: significant; 2D: two-dimensional; 3D: three-dimensional; MSV: multislice view

detection of hysterectomy in the subjects were disruption of the uterine serosa-bladder interface (90.9% sensitivity, 68.8% specificity and 47% PPV) and crowded vessels over the peripheral sub-placental zone (93.2% NPV). In addition, the best 3D MSV Doppler parameters for the detection of hysterectomy were disruption of the hyperechoic serosa-bladder interface (100% sensitivity, 71.8% specificity, and 50% PPV) and crowded vessels over the peripheral sub-placental zone (100% NPV) (Table 7). Logistic regression analysis showed that the observation of the risk of difficult placental separation and considerable intraoperative blood loss was increased 60 times with disruption of the hyperechoic serosa-bladder interface and 83 times with abnormal placental lacunae or numerous coherent vessels involving the serosa-bladder interface by the 3D MSV Doppler (Table 8).

## Discussion

Hemorrhagic and surgical complications associated with MAP depend on the depth of placental invasion and involvement of adjacent structures (23). MAP with bladder invasion is a serious condition, which necessitates proper antenatal diagnosis and an appropriate management strategy (24).

A past history of cesarean delivery and placenta previa are the two risks for MAP, and the incidence of MAP is increased concomitantly with increased cesarean section rates (3, 25-27). Antenatal diagnosis of MAP is crucial for proper counseling for possible surgical complications, multidisciplinary team care, and recruitment (3). Recently, MRI has also been proposed as a diagnostic modality with promising results for the detection of MAP. Despite its cost and unavailability in many centers, MRI should be reserved for cases with inconclusive sonographic findings (13, 15, 17).

Recently, 3D ultrasound and the 3D power Doppler have been introduced for the detection of MAP, and MSV technology was introduced in 2004 (28). MSV represents the sequential sections of the scanned ROI, similar to MRI technology. Scanned ROI can be rotated and slices can be changed to obtain the best plane for analysis. The 3D MSV Doppler was previously used in the diagnosis of uterine anomalies and in the prenatal diagnosis of the fetal facial, heart, and central nervous system anomalies (20).

Fifty women at  $\geq$ 28 weeks gestation with suspected MAP (placenta previa anterior covering the scar of the previous cesarean section) were included in this study and scanned with 2D

Variables	Women who required emergency hysterectomy (number=11)	Women who did not require hysterectomy (number=39)	p significance
2D gray-scale findings	1		
Loss of the retro-placental sonolucent space	11 (100%)	13 (33.3%)	0.03 (S)
Irregular retro-placental sonolucent area	11 (100%)	12 (30.8%)	0.02 (S)
Disruption of the uterine serosa-bladder interface	9 (81.8%)	7 (17.9%)	0.01 (S)
Exophytic mass invading the bladder	4 (36.4%)	2 (5.1%)	0.02 (S)
Abnormal placental lacunae	8 (72.7%)	26 (66.7%)	0.8 (NS)
3D power Doppler findings	1		L
Disruption of the uterine serosa-bladder interface	10 (90.9%)	8 (20.5%)	0.008 (S)
Numerous vessels invading the serosa-bladder interface	6 (54.5%)	24 (61.5%)	0.8 (NS)
Crowded vessels over the peripheral sub-placental zone	10 (90.9%)	12 (30.8%)	0.04 (S)
Abnormal placental lacunae	10 (90.9%)	11 (28.2%)	0.03 (S)
3D MSV Doppler findings			
Disruption of the hyperechoic serosa-bladder interface	11 (100%)	11 (28.2%)	0.01 (S)
Numerous coherent vessels invading the serosa-bladder interface	8 (72.7%)	25 (64.1%)	0.8 (NS)
Crowded vessels over the peripheral sub-placental zone	11 (100%)	15 (38.5%)	0.06 (S)
Abnormal placental lacunae	11 (100%)	14 (35.9%)	0.04 (S)
Data represented as number and percentage, analysis using chi-square $(X^2)$	) test.		

#### Table 5. 2D gray-scale, 3D power Doppler, and 3D MSV Doppler findings in women who required emergency hysterectomy to stop bleeding compared with women who did not require hysterectomy

NS: non-significant; S: significant; 2D: two-dimensional; 3D: three-dimensional; MSV: multislice view

# Table 6. Accuracy of 2D gray-scale, 3D power Doppler, and 3D MSV Doppler parameters in the prediction of difficult placental separation and considerable intraoperative blood loss

Variables	Sensitivity	Specificity	PPV	NPV
2D gray-scale findings		· · · · ·		
Loss of the retro-placental sonolucent space	70%	59.3%	64.%	74.2%
Irregular retro-placental sonolucent area	72.6%	63%	65.5%	71%
Disruption of the uterine serosa-bladder interface	43.5%	88.9%	76.9%	64.9%
Exophytic mass invading the bladder	26.1%	100%	100%	61.4%
Abnormal placental lacunae	73.9%	37%	50%	62.5%
3D power Doppler findings		1		1
Disruption of the uterine serosa-bladder interface	77.2%	82.2%	79.7%	79.9%
Numerous vessels invading the serosa-bladder interface	71.3%	69.4%	65.1%	76.2%
Crowded vessels over the peripheral sub-placental zone	79.6%	71.8%	73%	82.2%
Abnormal placental lacunae	65.6%	36.5%	42.1%	56.8%
3D MSV Doppler findings				
Disruption of the hyperechoic serosa-bladder interface	78.3%	85.2%	81.8%	82.1%
Numerous coherent vessels the invading serosa-bladder interface	78.3%	70.4%	69.2%	79.2%
Crowded vessels over the peripheral sub-placental zone	82.6%	77.8%	76%	84%
Abnormal placental lacunae	69.6%	37%	48.5%	58.5%
Data represented as percentage.				1

PPV: positive predictive value; NPV: negative predictive value; 2D: two-dimensional; 3D: three-dimensional; MSV: multislice view

gray-scale ultrasound, power Doppler, and 3D MSV Doppler to confirm the diagnosis of MAP. Intraoperative findings and histopathology results of the removed uteri were compared with preoperative sonography findings to evaluate the accuracy of the 3D MSV Doppler in the diagnosis of MAP. Of the total subject population, 46 were delivered at 35 weeks by planned cesar-

Variables	Sensitivity	Specificity	PPV	NPV
2D gray-scale findings	1	•		
Loss of the retro-placental sonolucent space	70%	48.7%	35.5%	70%
Irregular retro-placental sonolucent area	70%	53.8%	37.9%	70%
Disruption of the uterine serosa-bladder interface	81.8%	82.1%	56.3%	84.1%
Exophytic mass invading the bladder	63.4%	94.9%	66.7%	84.1%
Abnormal placental lacunae	72.7%	33.3%	23.5%	81.3%
3D power Doppler findings	ł			
Disruption of the uterine serosa-bladder interface	90.9%	68.8%	47%	90.8%
Numerous vessels invading the serosa-bladder interface	90.9%	60.5%	40.3%	92.2%
Crowded vessels over the peripheral sub-placental zone	90.9%	61.1%	41%	93.2%
Abnormal placental lacunae	62.7%	32.9%	21.2%	82.4%
3D MSV Doppler findings				
Disruption of the hyperechoic serosa-bladder interface	100%	71.8%	50%	100%
Numerous coherent vessels invading the serosa-bladder interface	100%	61.5%	42.3%	100%
Crowded vessels over the peripheral sub-placental zone	100%	64.1%	44%	100%
Abnormal placental lacunae	72.7%	35.9%	24.2%	82.4%
Data represented as percentage. PPV: positive predictive value; NPV: negative predictive value; 2D: two-dimensi	onal; 3D: three-dime	nsional; MSV: multi	slice view	-

### Table 7. Accuracy of 2D Gray-Scale, 3D power Doppler, and 3D MSV Doppler parameters in the prediction of hysterectomy

# Table 8. Logistic regression analysis of 2D gray-scale, 3D power Doppler, and 3D MSV Doppler parameters as predictors of difficult placental separation and considerable intraoperative blood loss

Ultrasound technique	Parameters	Difficult placental separation and considerable intraoperative blood loss	Odds ratio (95% confidence interval)
2D gray-scale	Loss of the retro-placental sonolucent space	26/7 2/15	27.8 (5.1–151.7)
	Irregular retro-placental sonolucent area	25/5 3/17	28.3 (5.9–134.6)
	Disruption of the uterine serosa- bladder interface	18/2 10/20	18 (3.5–93.4)
	Exophytic mass invading the bladder	8/0 20/22	18.6 (1.01–343.9)
	Abnormal placental lacunae	21/14 7/8	1.7 (0.50–5.80)
3D power Doppler	Disruption of the uterine serosa- bladder interface	22/6 6/16	9.7 (2.6–35.9)
	Abnormal placental lacunae	22/6 6/16	9.7 (2.6–35.9)
	Numerous vessels invading the serosa- bladder interface	22/6 6/16	9.7 (2.6–35.9)
	Crowded vessels over the peripheral sub-placental zone	17/15 11/7	0.7 (0.2–2.3)
3D MSV Doppler	Disruption of the hyperechoic serosa-bladder interface	24/2 4/20	60 (9.9–362.3)
	Abnormal placental lacunae	25/2 3/20	83.3 (12.6–547.9)
	Numerous coherent vessels invading the serosa-bladder interface	25/2 3/20	83.3 (12.6–547.9)
	Crowded vessels over the peripheral sub-placental zone	17/14 11/8	0.8 (0.2–2.7)
2D: two-dimens	ional; 3D: three-dimensional; MSV: multislice view		

ean section, while four were delivered at 33 weeks because of antepartum hemorrhage. In this study, parity and the number of previous cesarean sections were significantly high among women who had difficult placental delivery, considerable intraoperative blood loss, who required emergency hysterectomy to control bleeding. Wright et al. (29) found that 41.7% of women with a known placenta accreta had a blood loss of  $\geq$ 5000 mL, and, although Wright et al. (29) concluded that there was no significant relation between parity, number of previous cesarean deliveries, degree of placental invasion, and massive blood loss, Tikkanen et al. (30) found that the risk factors of placenta accreta included parity, cesarean section, and placenta previa. In addition, Guleria et al. (31) concluded that the risk factors of abnormal invasive placentation (AIP) were placenta previa and a past history of cesarean delivery, and Thia et al. (32) concluded that the depth of invasion in MAP is increased with multiple previous surgeries or excessive curettage or infection causing defective decidua basalis. D'Antonio et al. (16) concluded that the incidence of AIP increased in the past decades as a consequence of increasing caesarean section rates, and ultrasound has 91% sensitivity and 97% specificity for the prediction of all forms of AIP. Bilateral internal iliac artery ligation was needed in 28% (14/50) of the subjects, intrauterine compression balloon with placenta bed sutures was needed in 6% (3/50) of the subjects, and cesarean hysterectomy was performed in 22% (11/50) of the subjects. Warshak et al. (33) reviewed 99 women with pathologically confirmed placenta accreta. Warshak et al. (33) concluded that antenatal detection of placenta accreta was associated with a significant decrease in maternal hemorrhage. In addition, Tikkanen et al. (30) concluded that the diagnosis of placenta accreta may significantly reduce peripartum blood loss, and Chantraine et al. (34) concluded that the prenatal diagnosis of AIP reduces morbidity and undiagnosed cases of AIP led to more emergency hysterectomies (33, 30, 34).

Eller et al. (35) concluded that planned cesarean hysterectomy and preoperative ureteric stents were associated with reduced maternal morbidity in MAP.

In this study, the best 2D gray-scale ultrasound parameters for the detection of difficult placental separation and considerable intraoperative blood loss were abnormal placental lacunae (73.9% sensitivity), exophytic mass invading the bladder (100% specificity & 100% PPV), and loss of the retro-placental sonolucent zone (74.2% NPV). In addition, the best 2D gray-scale ultrasound parameters for the detection of emergency hysterectomy in the subjects were disruption of the hyperechoic uterine serosa-bladder interface (81.8% sensitivity) and exophytic mass invading the bladder (94.9% specificity, 66.7% PPV, and 84.1% NPV).

Thirty-two women were included in the study conducted by Dwyer et al. (15) that was conducted to compare the accuracy of trans-abdominal ultrasound and MRI for the diagnosis of placenta accreta. Sonography correctly identified placenta accreta with 93% sensitivity (14/15 cases) and ruled out placenta accret ta with 71% specificity (12/17 cases), whereas MRI correctly identified placenta accreta with 80% sensitivity (12/15 cases) and ruled out placenta accreta with 65% specificity (11/17 patients cases) (15). Warshak et al. (13), found that ultrasound

accurately diagnosed MAP with 77% sensitivity (30/39) and ruled out MAP with 96% specificity (398/414) and concluded that MRI may be helpful in the diagnosis of MAP in cases with equivocal or inconclusive ultrasound findings. A See comment in PubMed Commons belowlarge prospective study of grayscale ultrasound for the diagnosis of MAP was conducted by Comstock et al. (36) to detect the accuracy of ultrasound in the detection of placenta accreta in high-risk patients. Although Comstock et al. (36) concluded that multiple vascular spaces inside the placenta (placental lacunae) was the most notable diagnostic sign for placenta accreta with high PPV and obliteration of retro-placental area is not a reliable sign for the diagnosis of placenta accreta, Wong et al. (37), concluded that the loss of the placental-uterine interface and the presence of abnormal vessels crossing this interface were the most specific criteria to diagnose MAP using 2D gray-scale ultrasound scan. Comstock et al. (36) found that the absence of the space between the placenta and myometrium is not a diagnostic sign for MAP because the space may be normally absent without MAP. They recommended the use of the color Doppler to identify placental sinuses crossing the uterine wall to the bladder.

In this study, the best 3D power Doppler parameters for the detection of difficult placental separation and considerable intraoperative blood loss in the subjects were crowded vessels over the peripheral sub-placental zone (79.6% sensitivity and 82.2% NPV) and disruption of the hyperechoic serosa-bladder interface (82.2% specificity and 79.7% PPV). In addition, the best 3D power Doppler parameters for the detection of emergency hysterectomy in the subjects were disruption of the uterine serosa-bladder interface (90.9% sensitivity, 68.8% specificity and 47% PPV) and crowded vessels over the peripheral sub-placental zone (93.2% NPV). Thirty cases of placenta previa were studied by Moodley et al. (17), and they found that two (66.6%) cases required caesarean hysterectomy and one (33.3%) case required internal iliac ligation to control bleeding. They concluded that the color flow Doppler was more specific in the diagnosis of MAP than MRI with 95% NPV (17). Zhang et al. (14) found that the color Doppler had 77.3% (17/22) sensitivity, 98.4% (189/192) specificity, 85.0% (17/20) PPV, and 97.4% (189/194) NPV in the diagnosis of placenta previa increta. Zhang et al. (14) concluded that the prenatal color Doppler ultrasound has a high sensitivity and specificity for the identification of placenta previa increta. Japaraj et al. (38) found that the prominent gray-scale ultrasound sign to diagnose placenta accreta was dilated vessels extending from the placenta to myometrium, and the most prominent color Doppler sign to diagnose placenta accreta was abnormal vessels connecting the placenta to bladder. In addition, Shi et al. (39) found that the most prominent grayscale sign to diagnose placenta accreta was dilated vessels extending from the placenta to the myometrium, and the most prominent color Doppler diagnostic sign was the presence of abnormal vessels connecting the placenta to the bladder. Shi et al. (40) found that numerous vessels observed by the 3D power Doppler was the best single diagnostic sign of placenta accreta, with 97% sensitivity, and they concluded that the 3D power Doppler is a useful tool for the diagnosis of MAP. Chou et al. (12) found that the color Doppler had 82.4% (14/17) sensitivity, 96.8%

(61/63) specificity, 87.5% (14/16), and 95.3% (61/64) positive and negative predictive values. Chou et al. (23), in another study, found a strong association between bladder invasion in MAP and 3D power Doppler findings, particularly hypervascularization of the uterine serosa-bladder interface and large rosette of varicosities in the area of bladder base. Chou et al. (23), concluded that 3D ultrasound can be used as an adjunctive tool with 2D ultrasound to identify the extent of invasion in cases of MAP. The advantages of 3D ultrasound are as follows: 1. Multiplanar image display (sagittal, coronal, and axial planes at the same time) and 2. Viewing planes of vasculature can be manipulated to identify vessels invading the bladder (23). In addition, Cali et al. (41) found that irregular tortuous vessels affecting the entire placenta and the uterine serosa-bladder interface were the diagnostic signs of MAP observed by the 3D power Doppler.

This study was the first study to evaluate the accuracy and advantages of the 3D MSV Doppler over the 3D power Doppler in the prenatal diagnosis of MAP. The advantages gained by MSV were as follows:

1. Multiplanar mode allows one to achieve standardized views in the acquisition plane (A plane) by rotating reconstructed planes (B and C planes),

2. Comparing several slices displayed on the same screen to obtain the most informative image that can confirm the diagnosis obtained by 2D gray-scale ultrasound (20).

The sensitivity and NPV (79.6% and 82.2%, respectively) of crowded vessels over the peripheral sub-placental zone to detect difficult placental separation and considerable intraoperative blood loss in the subjects with MAP using the 3D power Doppler were increased to 82.6% and 84%, respectively, using the 3D MSV Doppler. In addition, the specificity and PPV (82.2% and 79.7%, respectively) of the disruption of the uterine serosa-bladder interface to detect difficult placental separation and considerable intraoperative blood loss using the 3D power Doppler was increased to 85.2% and 81.1%, respectively, using the 3D MSV Doppler (this difference was statistically insignificant). The sensitivity, specificity and PPV (90.9%, 68.8%, and 47%, respectively) of disruption of the uterine serosa-bladder interface for the detection of emergency hysterectomy in the subjects with MAP using the 3D power Doppler were increased to 100%, 71.8%, and 50%, respectively using the 3D MSV Doppler. The NPV (93.2%) of crowded vessels over the peripheral subplacental zone for the detection of emergency hysterectomy using the 3D power Doppler was increased to 100% using the 3D MSV Doppler, (this difference was statistically insignificant). Two women who were afraid of a loss of their privacy and thus refused to participate in this study and small published data about the use of the 3D MSV Doppler in MAP were the limitations faced during this study.

In conclusion, the 3D MSV Doppler increased the predictive value of the diagnostic criteria of MAP compared with the 3D power Doppler, although this increase was not significant. More randomized studies with higher power are necessary to conclude this type of adjunctive use.

*Ethics Committee Approval:* Ethics committee approval was received for this study from the ethics committee of Ain Shams University Maternity Hospital, Cairo, Egypt. Informed Consent: Written informed consent was obtained from patients who participated in this study. Peer-review: Externally peer-reviewed.

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