Detecting the Accuracy of Three Dimensional Power Doppler (3DPD) Vascular Indices for Prenatal Diagnosis of Morbidly Adherent Placenta in Patients with Placenta Previa

Original Article

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ABSTRACT

Background: Traditionally, 2D ultrasound have been used for the diagnosis of a suspected morbidly adherent placenta previa. Recently, 3D power Doppler technique was introduced to diagnose morbidly adherent placenta (MAP).

Aim: The study objective was to assess the accuracy of prenatal 3-dimensional power Doppler analysis of vascular and flow placental indices to predict the morbidly adherent placenta objectively.

Materials and Methods: A prospective study executed among women with placenta previa between 28 and 32 weeks of gestation. Patients were examined by 2D ultrasounds which was used in management decisions. 3D Power Doppler vascular, flow and vascular flow indices were measured during the same examination after tracing of maximum placental thickness; data were blinded to obstetricians. Histopathology was used to confirm MAP. Severe morbidly adherent placenta was described as increta/percreta on histopathology, blood loss >2L, and >2 units of PRBC transfused. Sensitivities, specificities, predictive values, and likelihood ratios were calculated.

Results: Our results showed that the 3D Doppler VI ≥ 16 predicted MAP with a 100% sensitivity ,100% specificity which are better than those of 2D ultrasound (60.0% and 89.1% respectively).

Sever MAP occurred in 51.2% of MAP and 3D Doppler of VI > 33.1 predicted sever MAP with a sensitivity of 73.9% and specificity of 86.4%, which was superior to 2D ultrasound.

Conclusion: In placenta previa patients, the vascular index accurately predicts the morbidly adherent placenta. Furthermore, vascular and vascular flow indices of 3D power Doppler were more predictive of severe cases of morbidly adherent placenta compared to 2D ultrasound.

Key Words: 3D color Doppler, morbidly adherent placenta, placental vascular indices

Received: 04 November 2019, **Accepted:** 18 August 2020

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ISSN: 2090-7265, February 2022, Vol.12, No. 1

INTRODUCTION

The placenta normally attaches to the uterine wall, however, there is a condition that occurs where the placenta attaches itself too deeply into the wall of the uterus[1-5].

This condition is known as placenta accreta, placenta increta, or placenta percreta depending on the severity and deepness of the placenta attachment. Approximately 1 in 2,500 pregnancies experiences placenta accreta, increta or percreta[6-11].

Formerly, it was referred to it as MAP (Morbidly Adherent Placenta). Recently there is varied terminology has been applied to this condition[12-15]; however, recent guidelines suggested that placenta accreta spectrum (PAS), which includes accreta, increta, and percreta (defined below), be used going forward according to FIGO[16].

The difference between placenta accreta, increta or percreta is determined by the severity of the attachment of the placenta to the uterine wall.

Placenta Accreta occurs when the placenta attaches too deep in the uterine wall but it does not penetrate the uterine muscle. Placenta accreta is the most common accounting for approximately 75% of all cases.

Placenta Increta occurs when the placenta attaches even deeper into the uterine wall and does penetrate into the uterine muscle. Placenta increta accounts for approximately 15% of all cases.

Placenta Percreta occurs when the placenta penetrates through the entire uterine wall and attaches to another organ such as the bladder. Placenta percreta is the least common of the three conditions accounting for approximately 5% of all cases.

 DOI:10.21608/ebwhj.2020.19086.1048

The specific cause of placenta accreta is unknown, but it can be related to placenta previa and previous cesarean deliveries. Placenta accreta is present in 5% to 10% of women with placenta previa[10,11].

A cesarean delivery increases the possibility of a future placenta accreta, and the more cesareans, the greater the increase. Multiple cesareans were present in over 60% of placenta accreta cases. Other risk factors that can increase the risk of placenta accreta, include:

Placenta position: If the placenta partially or totally covers your cervix (placenta previa) or sits in the lower portion of your uterus, you're at increased risk of placenta accreta.

Maternal age: Placenta accreta is more common in women older than 35year.

Previous childbirth: The risk of placenta accreta increases as your number of pregnancies increases[11].

Premature delivery and subsequent complications are the primary concerns for the baby. Bleeding during the third trimester may be a warning sign that placenta accreta exists, and when placenta accreta occurs it commonly results in premature delivery.

The placenta usually has difficulty separating from the uterine wall. The primary concern for the mother is hemorrhaging during manual attempts to detach the placenta. Severe hemorrhaging can be life-threatening. Other concerns involve damage to the uterus or other organs (percreta) during removal of the placenta. Hysterectomy is a common therapeutic intervention, but the results in volve the loss of the uterus and the ability to conceive.

AIM OF THE WORK

The study objective was to assess the accuracy of prenatal 3-dimensional power Doppler analysis of vascular and flow placental indices to predict the morbidly adherent placenta objectively.

PATIENTS AND METHODS

This was a prospective cohort study conducted between September 2018 and September 2019 at the Departments of Obstetrics and Gynecology, Ain Shams University Maternity Hospital.

Inclusion criteria: women who were referred to the ultrasound for the re-evaluation of placenta previa and morbidly adherent placenta between 28 and 32 weeks will be included.

Exclusion criteria: Fetal anomalies and multiple gestations.

Combination of trans abdominal and transvaginal ultrasound performed to confirm the location of placenta using routine 2D imaging. Uniform diagnostic criteria will be applied to diagnose the suspected MAP using at least one of the following findings:

The presence of hypo echoic areas in the body of the placenta (placental lacunae).

The loss of the normal hypo echoic myometrium adjacent to the base of the placenta (loss of sonolucency).

Absent or disrupted hyper echoic line separating the uterus from the urinary bladder (abnormal uterine serosa-bladder line). They have all been identified as markers of MAP on 2D ultrasound[3].

Then if one of the above mentioned criteria was found pregnant women underwent an additional imaging using 3D power Doppler transabdominal ultrasound of the placenta. After confirming the full bladder, 3D power Doppler images were obtained using a GE Voluson E8 RAB4-8 transducer probe with the following standardized settings: smooth: 4/5, FRQ: low, quality: high, density: 6, enhance: 16, balance: GO150, filter: 2, pulse repetition frequency: 0.9 kHz, power 100%, gain -5.4 and wall motion filter low[22,5,13]. This technique for the evaluation of placental vascularity has been previously described[13,12].

The placental imaging was optimized for every patient to visualize the maximum placenta with the suspected MAP site at the center of the imaging area. The 3D placental volume was obtained by imaging the placenta sagittally. An 85° angle of acquisition (the maximum that can be acquired) was used and the patient was asked to hold her breath during the acquisition to improve image quality.

The placental images were optimized for every patient to visualize the maximum placenta with the suspected MAP at the center of the imaging area. Histogram analysis was applied to the taken images. The 3D placental volumes were assessed by manual tracing at 30º angle increments to include the maximum viewed placenta. The vascularization index (VI; the proportion of colored/total voxels, voxels being the cubes that occupy the volume of interest, which is in this case the placenta), the flow index (FI; the mean color value of all blood flow or the average intensity of the colored voxels), and the vascular flow index (VFI; a combination of vascularization and flow information relating the weighted color values to the cube obtained by multiplying VI by FI and dividing the result by 100 were calculated using the same software[22,18,4]. Once the placenta was traced and histogram software was applied, results were instantly obtained. Data was blinded to the maternal fetal medicine specialist interpreting the 2D ultrasound findings and making recommendations for the decision making of the patient's management of care. 2D findings were also blinded to the provider (first author) performing the 3D technique and calculating VI, FI and VFI.

Women were followed prospectively until delivery and data was collected from the patients' medical record including a review of the operative and pathology reports. Patients underwent cesarean delivery followed

by hysterectomy (cesarean hysterectomy) as determined by the operative physician- based on the following discussion. The combination of suspected diagnosis from 2D ultrasound and clinical assessment were used as tools to make the decision at the discretion of the physician.

To plan for delivery under controlled surgical and hematological conditions, women with a MAP diagnosis on 2D ultrasound were co-managed by a multidisciplinary team that included maternal-fetal medicine specialists, gynecologic, neonatologists, anesthesiologists, intensive care physicians, and in some cases vascular and urology surgeons. At the time of surgery, the primary surgeon's decision to proceed with hysterectomy leaving the placenta in situ was made based on the complexity and size of the external uterine wall vasculature and/or the presence of obvious placental invasion.

If 2D findings were not suspicious for MAP, a hysterectomy was performed when the placental invasion was noted with increased vascular markings and visualization of placenta through the uterine window, when the placenta failed to separate spontaneously, or when resistance to manual placental separation with or without heavy bleeding was encountered.

The final diagnosis of MAP for the analysis in this study was made based on the pathological examination of hysterectomy specimen by a perinatal pathologist (N.T.), which included the presence of accreta, increta, or percreta. (Abuhamad 2013) Placenta accreta was diagnosed when placental villi were attached to the myometrium, increta when placental villi invaded into the myometrium and percreta when the invasion was through the myometrium[3].

The patients were divided according to the collected data into 2 groups (group A and group B); Group (A) patients without MAP and Group (B) patients with MAP confirmed by histopathological examination of hysterectomy specimen and according to this examination they were sub grouped into MAP and sever MAP.

Severe MAP (sMAP) which was defined for the study by the presence of all the following components; increta or percreta on histopathology, transfusion of ≥ 2 units of packed red blood cells and calculated blood loss > 2000 ml and blood loss > 2000 ml was considered severe based on previous reviews[23]

STATISTICAL ANALYSIS

The collected data were coded, tabulated, and statistically analyzed using IBM SPSS statistics (Statistical Package for Social Sciences) software version 18.0, IBM Corp., Chicago, USA, 2009.

Descriptive statistics were done for quantitative data as minimum and maximum of the range as well as mean±SD (standard deviation) for quantitative normally distributed data, median and 1st and 3rd inter-quartile range for quantitative non-normally distributed data, while it was done for qualitative data as number and percentage.

Inferential analyses were done for quantitative variables using Shapiro-Wilk test for normality testing, independent t-test in cases of two independent groups with normally distributed data and, ANOVA test with for more than two independent groups with normally distributed data and Kruskal Wallis test with non-normally distributed data. In qualitative data, inferential analyses for independent variables were done using Chi square test for differences between proportions and Fisher's Exact test for variables with small expected numbers as well as Kappa and test for agreement between paired categorical data. Post hoc Bonferroni test to find homogenous groups in significant tests among more than two independent groups. ROC curve was used to evaluate the performance of different tests differentiate between certain groups. The level of significance was taken at *P value* < 0.050 is significant, otherwise is non-significant.

Diagnostic characteristics were calculated as follows; the diagnostic sensitivity: it is the percentage of diseased cases truly diagnosed (TP) among total diseased cases (TP+FN). The diagnostic specificity: it is the percentage of non-diseased truly excluded by the test (TN) among total non-diseased cases (TN+FP). The predictive value for a +ve test: it is the percentage of cases truly diagnosed among total positive cases; the predictive value for a -ve test: it is the percentage of cases truly negative among total negative cases. The efficacy or the diagnostic accuracy of the test: it is the percentage of cases truly diseased plus truly non-diseased among total cases; likelihood ratio-negative; it measures how likely a patient has no disease or condition; likelihood ratio-positive; it measures how likely a patient has a disease or condition. Diagnostic accuracy=([True positive test +True negative test]/Total cases)x100. Youden's index=sensitivity+specificity-1.Kappa=observed agreement-expected agreement / (1-expected agreement).

RESULTS

A total of 131 women were identified to have placenta previa between September 2018 and September 2019; ten of them had a gestational age at recruitment of either < 28 weeks or > 32 weeks (The gestational age window was chosen based on the usual time of referral to re-evaluate the placental location when a previa was suspected), two had fetal anomalies, three had a twin gestation, and five declined to participate. Of 111 enrolled cases, six were excluded due to the inability to entirely view the borders of the placenta in one sweep (four of them had an accessory lobe and the study was technically challenging in the other two because of maternal habitus) and lost to follow up in another five patients. 100 cases were analyzed. Overall, 98 patients were multigravida and 97 patients were multiparous. The overall mean maternal age among studied cases was 31.0±5.5

years. while the gestational age at the time of the scan was 33.9±2.4 weeks and at the delivery was 35.6±2.1 weeks.

There were 7 cases have history of D and C and 2 cases underwent myomectomy, no other uterine surgeries were reported. Median of cases underwent previous CD was 2.0 with IQR of (0.0-3.0) and range between (0.0-4.0). All cases were delivered by C.S 97% of them underwent LUS C.S. Seven cases suffered from visceral injuries (4 cases had bladder injuries, 2 had ureteric injuries and one case had rectal injuries) and 2 cases were admitted to the ICU with mean estimated blood loss of 1.5±1.2 L.

The most common placental location was anterior 87%, 7% were posterior most of them were in no MAP group and 6% with lateral extension. Of all patients who delivered by cesarean section, thirty-three cases were clinically diagnosed with MAP based on 2D parameters before the delivery event; 27 of them underwent a cesarean hysterectomy and were confirmed MAP by histopathology. Among the remaining 6 cases, four had a cesarean delivery without hysterectomy because the placenta separated easily intraoperatively and the remaining two cases had a cesarean hysterectomy with no histological evidence of MAP (both patients suffer of sever uncontrollable intraoperative bleeding).

Sixty-seven case where 2D diagnosis was no apparent criteria for MAP diagnosis using the same parameters, eighteen had a hysterectomy due to adherent placenta during the cesarean delivery and were subsequently confirmed to have MAP by histopathology.

The rest of them (49 cases) underwent a cesarean delivery only. (Of 47 women who had a cesarean hysterectomy, forty-five (95.74%) had confirmed MAP based on the histopathological examination of the hysterectomy specimen;21 were accreta, 13 increta, and 11 percreta.

Comparing the demographic characteristics and pregnancy outcomes between women with MAP vs no MAP, there was no difference in gestational age at the time of the ultrasound examination, hypertension, or diabetes. Among the 45 women with confirmed MAP, the median of women who had at least one prior CD was (2.0) and IQR of (1.0-3.0), compared to (1.0) and (0.0-3.0) with no MAP ($p = 0.002$).

As expected, pregnancies with confirmed MAP were more complicated than those who had no MAP: MAP had more blood loss ($p<0.001$), more blood transfusions ($p<0.01$), more intra-operative injuries ($p<0.01$) and more ICU admissions ($p<0.01$). Prediction of MAP using 3D Doppler indices.

Prediction of MAP using 3D Doppler indices: Figure 1 illustrated a 3D analysis of vascular indices and an ultrasound comparison of a placenta with MAP and No MAP, respectively.

When the 3D Doppler indices were compared between pregnancies with MAP and those with no MAP, the mean values of VI and VFI were significantly higher in the confirmed MAP group (Table 1; $p < 0.001$ both). FI values were similar in both groups (p =0.181).

ROC curves were constructed to assess the ability VI, FI, VFI to predict a morbidly adherent placenta and an area under the curve (AUC) was calculated for each parameter (Figure 2). Among the 3D Doppler indices, VI had the highest AUC of 1.000 (95% CI1.000–1.000) and FI had the lowest (AUC =0.629, 95% CI 0.510–0.748) (Table 2, Figure 2). VI ≥ 16 predicted the diagnosis of MAP with a 100% sensitivity (95% CI92.1%–100.0%), 100.0% specificity (95% CI 93.5%–100.0%), 100.0% PPV (95% CI 92.1%–100.0%), 100.00% NPV (95% CI 93.5%–100.0%), LR+ >100.0 (95%CI >100.0–>100.0%), and LR– 0.00 (95% CI 0.00-0.00) (Table 4).

sMAP was found in 23/45 (51.2%) patients. The median (range) of blood transfusion of packed red blood cells in sMAP subgroup were 5 (2-12) and the calculated blood loss volume was on average 3.5±0.9L. The placenta pathology in the sMAP was 7 incretas and 11 percretas. Similarly, using VI, FI, and VFI for the prediction of severe MAP, VI had the highest AUC compared to the other parameters (Figure 3, Table 3). VI ≥ 33.1 predicted sMAP with an 73.9% sensitivity (95% CI51.6%–89.8%),86.4%, specificity (95%CI65.1%–97.1%),85.0%PPV (95% CI 62.1%-96.8%), 85.70% NPV (95%CI 54.9%-90.6%) (Table 5). Table 3 and Figure 3 showed that only VI had significant moderate diagnostic performance in differentiating sMAP from non-sMAP.

Comparing 2D findings and 3d findings: Comparing of obtained data of all the studied cases to assess the best diagnostic method for prediction of MAP and sMAP weather 2D or 3D power Doppler. This comparison is better seen in Tables 4,5.Our study assessed the entire viewed placenta. We found a significant increase of VI in MAP cases in the current study. This strongly suggests that the use of the 3D Doppler vascular index (VI) can accurately predict the diagnosis of morbidly adherent placenta by quantifying the colored voxels within the placental volume indicating an increased vascularity.

Furthermore, the values are higher when the clinical severity is increased. The sensitivity and the negative predictive value in predicting sMAP can reach 100% when a threshold value for VI of greater than 33.1 is used. Similar increases were seen with VFI. However, we found that FI was not increased in association with MAP.

Table 5: VI ≥16.0 and VFI ≥11.0 had perfect diagnostic characteristics in differentiating MAP from non-MAP. 2D and FI≥42.8 had significant low diagnostic characteristics in differentiating MAP from non-MAP.

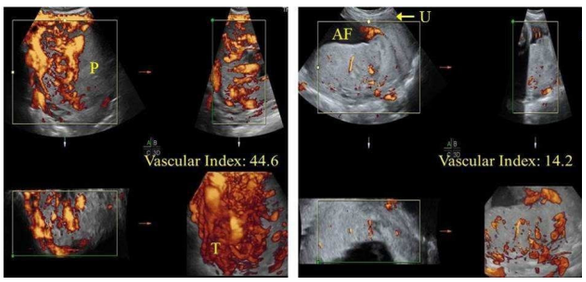

Fig. 1: Ultrasound comparison of 3D Doppler placenta between MAP with percreta (left) and No MAP (right), P, placenta; AF, amniotic fluid; U, uterine wall; T, tortuous vessels

Table 1: 3D Power Doppler indices in both groups MAP and No MAP

Characteristics		MAP (N=45)	No MAP (N=55)	*p*
3D indices	VI	31.4±4.5	12.7±1.1	^<0.001*
	FI	42.5±1.3	42.2±0.9	^0.181
	VFI	14.8±0.8	5.1±1.0	^<0.001*

^Independent t-test, *Significant

Table 2 and Fig. 2: VI and VFI had significant perfect diagnostic performance in differentiating MAP from non-MAP. FI had significant low diagnostic performance in differentiating MAP from non-MAP.

Indices	AUC	SE	P	95% CI	Cut off
VI	1.000	0.000	<0.001*	1.000–1.000	≥16.0
FI	0.629	0.061	0.027*	0.510–0.748	≥42.8
VFI	1.000	0.000	<0.001*	1.000–1.000	≥11.0

AUC: Area under curve, SE: Standard error, CI: Confidence interval, *significant

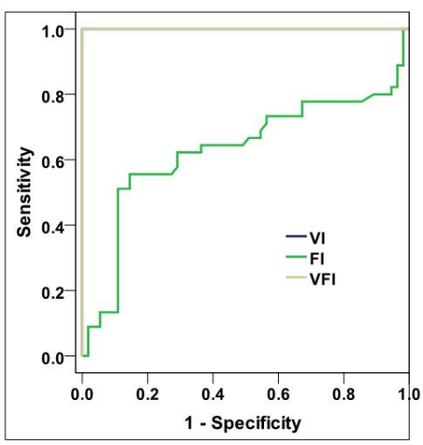

Fig.2: ROC curve in the prediction in differentiating MAP from non-MAP (VI and VFI are overlapping)

Table 3: Diagnostic performance of 3D indices in differentiating sMAP from non-sMAP

Indices	AUC	SE	P	95% CI	Cut off
VI	0.751	0.080	0.004*	0.595–0.907	≥33.1
FI	0.662	0.083	0.063	0.500–0.824	≥43.0
VFI	0.646	0.084	0.093	0.481–0.811	≥15.0

AUC: Area under curve, SE: Standard error, CI: Confidence interval, *significant

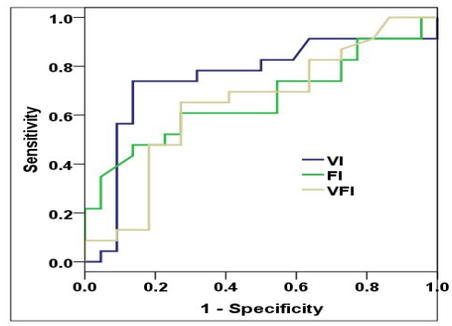

Fig. 3: ROC curve in differentiating sMAP from non-sMAP

Table 4: Diagnostic characteristics of 2D and 3D in differentiating MAP from non-MAP

Characters	Value	95% CI	Value	95% CI
	2D		VI≥16.0	
Sensitivity	60.0%	44.3%–74.3%	98.1%	89.1%–99.3%
Specificity	89.1%	77.8%–95.9%	96.3%	93.5%–98.6%
DA	76.0%	66.4%–84.0%	97.4%	96.4%–100.0%
Youden's index	49.1%	32.6%–65.6%	94.4%	91.5-97.5%
PPV	81.8%	64.5%–93.0%	93.12%	85.5-96.3%
NPV	73.1%	60.9%–83.2%	90.7%	80.9-94.3%
LR+	5.50	2.49–12.14	11.45	8.06-13.75%
LR-	0.45	0.31–0.65	0.05	0.03-0.13
	FI≥42.8		VFI≥11.0	
Sensitivity	62.2%	46.5%–76.2%	98.1%	89.1%–99.3%
Specificity	70.9%	57.1%–82.4%	96.3%	93.5%–98.6%
DA	67.0%	56.9%–76.1%	97.4%	96.4%–100.0%
Youden's index	33.1%	14.6%–51.7%	94.4%	91.5-97.5%
PPV	63.6%	47.8%–77.6%	93.12%	85.5-96.3%
NPV	69.6%	55.9%–81.2%	90.7%	80.9-94.3%
LR+	2.14	1.34–3.43	11.45	8.06-13.75%
LR-	0.53	0.35–0.80	0.05	0.03-0.13

CI: Confidence interval, DA: Diagnostic accuracy, PPV: Positive Predictive value, NPV: Negative Predictive value, LR+: Positive likelihood ratio, LR-: Negative likelihood ratio.

Table 5: Diagnostic characteristics of 2D and 3D indices in differentiating sMAP from non-sMAP

Characters	Value	95% CI	Value	95% CI
	2D		VI≥33.1	
Sensitivity	69.6%	47.1%–86.8%	73.9%	51.6%–89.8%
Specificity	50.0%	28.2%–71.8%	86.4%	65.1%–97.1%
DA	60.0%	44.3%–74.3%	80.0%	65.4%–90.4%
Youden's index	19.6%	-8.5%–47.7%	60.3%	37.3%–83.2%
PPV	59.3%	38.8%–77.6%	85.0%	62.1%–96.8%
NPV	61.1%	35.7%–82.7%	76.0%	54.9%–90.6%
LR+	1.39	0.85–2.29	5.42	1.84–15.95
LR-	0.61	0.29–1.28	0.30	0.15–0.61
	FI≥43.1		VFI≥15.0	
Sensitivity	60.9%	38.5%–80.3%	47.8%	26.8%–69.4%
Specificity	68.2%	45.1%–86.1%	81.8%	59.7%–94.8%
DA	64.4%	48.8%–78.1%	64.4%	48.8%–78.1%
Youden's index	29.1%	1.2%–56.9%	29.6%	3.6%–55.7%
PPV	66.7%	43.0%–85.4%	73.3%	44.9%–92.2%
NPV	62.5%	40.6%–81.2%	60.0%	40.6%–77.3%
LR+	1.91	0.96–3.83	2.63	0.98–7.04
LR-	0.57	0.32–1.03	0.64	0.41–0.99

CI: Confidence interval, DA: Diagnostic accuracy, PPV: Positive Predictive value, NPV: Negative Predictive value, LR+: Positive likelihood ratio, LR-: Negative likelihood ratio.

DISCUSSION

This prospective cohort study was conducted at Ain Shams University Maternity Hospital at the department of Obstetrics and Gynecology in the period from September 2018 to September 2019.

The population of this study was 100 pregnant women with placenta previa women who were referred to the ultrasound unit for the evaluation of placenta previa and morbidly adherent placenta between 28 and 32 weeks of gestation who were admitted to Ain Shams University Maternity Hospital and planned for elective lower segment cesarean section and were allocated in 2 groups after delivery; group Aincluded patients without MAP and group B included patients with MAP confirmed by histopathological examination of hysterectomy specimen and according to this examination they will be sub grouped into MAP and sever MAP.

Women with fetal anomalies and multiple gestations were excluded from our study. Combination of transabdominal and transvaginal ultrasound was performed to confirm the location of placenta using routine 2D imaging.

The uniform diagnostic criteria were applied to diagnose the suspected MAP, then if one of these criteria was found the pregnant women underwent additional imaging using 3D power Doppler transabdominal ultrasound of the placenta after confirming full bladder. The placental images were optimized for every patient to visualize the maximum placenta with the suspected MAP at the center of the imaging area. The 3D placental volume was obtained by imaging the placenta sagittally. Histogram analysis was applied to the taken images. The 3D placental volumes were assessed by manual tracing at 30º angle increments to include the maximum viewed placenta. The volume of the placenta was documented. The vascularization index (VI), the flow index (FI) and the vascular flow index (VFI) were calculated using the same software. Once the placenta was traced and histogram analysis was applied, results were obtained.

Our results showed that the 3D color Doppler VI ≥ 16 predicted the diagnosis of MAP with a 100% sensitivity ,100% specificity which are better than those of 2D ultrasound (60.0% and 89.1% respectively).

Sever MAP occurred in 51.2% of MAP and 3D color Doppler of VI > 33.1 predicted sever MAP with a sensitivity of 73.9% and specificity of 86.4%, which was superior to 2D ultrasound.

In the current study the sensitivity and the specificity of 2D ultrasound for the diagnosis of MAP was 60.0% and 89.1% respectively when at least one abnormal parameter was present. The sensitivity and specificity dropped to 69.6% and50.0% respectively when severe MAP was the outcome.

A recent systematic review showed a wide heterogeneity in terminology used to describe the grades of accreta placentation using the 2D parameters[16]. The authors concluded that the evaluation of the accuracy of ultrasound imaging in screening and diagnosing placenta accreta is limited[16]. In the same review, when combining all cases of placenta accreta, increta and precreta, the loss of sonolucency was the most common finding[16].

Several studies used the 3D color Doppler technique to diagnose MAP and reported a sensitivity ranging between 39 and 100% based on abnormal vascular patterns.

In these studies, the placenta was assessed subjectively for abnormal vascularity using the 3D power Doppler technique without any quantification.[22] made the diagnosis of placenta accreta when intra placental hypervascularity, inseparable cotyledonal (fetal) and intervillous (maternal) circulations, or tortuous vascularity was noted[22].

Hypervascularity of the uterine serosa–bladder wall interface and tortuous confluent vessels across the placental width were used as diagnostic criteria for morbidly adherent placenta[5] A recent study quantified the amount of vessels involved in the diagnosis of morbidly adherent placenta[6]. However, this was applied to the utero-placental interface only and not the entire placenta. They measured the largest area of confluent 3D power Doppler signal[6]. Although abnormal vascularity of the utero-placental interface is highly suggestive of abnormal

placentation, abnormal vessels running throughout the placenta could be missed using this particular technique. In addition, choosing the most confluent area is operator dependent and other areas might have been missed due to subjectivity of the operator's assessment[2] study which evaluated the accuracy of gray-scale and three-dimensional power Doppler ultrasound parameters in the diagnosis of morbidly adherent placenta agreed with us and stated that 3D power Doppler is a useful complementary tool to 2D gray-scale ultrasound for antenatal diagnosis of MAP. Crowded vessels over peripheral sub-placental zone and disruption of uterine serosa–bladder interface were the best 3D power Doppler parameters for the detection of difficult placental separation, considerable intraoperative blood loss, and emergency hysterectomies in the studied cases. Fifty pregnant women ≥28 weeks' gestation with suspected MAP were included randomly in this prospective study.

Two-dimensional (2D) transabdominal gray-scale ultrasound and 3D power Doppler scans were done for studied women to confirm placental location and findings suggestive of MAP.

Intraoperative findings and histopathology results of removed uteri in the cases were managed by hysterectomies compared to preoperative sonographic findings using Student's t-test and Mann–Whitney U-test for quantitative data, Chi-square test for qualitative data to detect the accuracy of 2D transabdominal gray-scale ultrasound and 3D power Doppler parameters in the diagnosis of MAP. Best 2D gray scale ultrasound parameters for the detection of emergency hysterectomies in the studied cases were disruption of uterine serosa – bladder interface (81.8% sensitivity) and exophytic mass invading bladder (94.9% specificity, 66.7% positive predictive value (PPV), and 84.1% negative predictive value [NPV]). Best 3D power Doppler parameters for the detection of emergency hysterectomies in the studied cases were disruption of uterine serosa–bladder interface (90.9% sensitivity, 68.8% specificity, and 47% PPV) and crowded vessels over peripheral subplacental zone (93.2% NPV)[1].

In line with us,[14] study which stated that vascular index accurately predicts the morbidly adherent placenta in patients with placenta previa. In addition, 3D Power Doppler vascular and vascular flow indices were more predictive of severe cases of MAP compared to 2D ultrasound. This objective technique may limit the variations in diagnosing MAP due to the subjectivity of 2D ultrasound interpretations. Prospective cohort study was performed in women between 28-32 weeks with known placenta previa.

Patients underwent a two-dimensional (2D) gray-scale ultrasound that determined management decisions. 3D power Doppler volumes were obtained during the same examination and vascular, flow, and vascular flow indices were calculated after manual tracing of the viewed placenta in the sweep; data was blinded to obstetricians. MAP was confirmed by histology. Severe MAP (sMAP) was defined as: increta/percreta on histology, blood loss > 2000 ml, and > 2 units of PRBC transfused. Sensitivities, specificities, predictive values and likelihood ratios (LR) were calculated. Student-t and Chi-square tests, logistic regression, receiver operating characteristic (ROC) curves, and intra and inter-rater agreements using Kappa statistics were performed. Fifty women were studied: 23 had MAP, of which 12 (52.2%) were sMAP. 2D parameters diagnosed MAP with a sensitivity of 82.6% (95% CI 60.4-94.2), a specificity of 88.9% (95% CI 69.7-97.1), positive predictive value 86.3% (95% CI 64.0-96.4), negative predictive value 85.7% (95% CI 66.4-95.3), LR+ 7.4 (95% CI 2.5-21.9), and LR- 0.2 (95% CI 0.08-0.48). 3) Mean values of vascular index (32.8±7.4) and vascular flow index (14.2±3.8) were higher in MAP ($p < 0.001$).

Area under the ROC curve for vascular and vascular flow indices were 0.99 and 0.97, respectively. Vascular index ≥ 21 predicted MAP with a sensitivity and a specificity of 95% (95% CI 88.2-96.9) and 91% respectively (95% CI 87.5-92.4), 92% positive predictive value (95% CI 85.5-94.3), 90% negative predictive value (95% CI 79.9-95.3), LR+ 10.55 (95% CI 7.06-12.75), and LR- 0.05 (95% CI 0.03-0.13).

For sMAP, 2D ultrasound had a sensitivity of 33.3% (95% CI 11.3-64.6), a specificity of 81.8% (95% CI 47.8-96.8), positive predictive value 66.7% (95% CI 24.1-94.1), negative predictive value 52.9% (95% CI 28.5- 76.1), LR+ 1.83 (95% CI 0.41-8.11), and LR- 0.81 (95% CI 0.52-1.26). A vascular index ≥ 31 predicted the diagnosis of sMAP with a 100% sensitivity (95% CI 72-100), 90% specificity (95% CI 81.7-93.8), 88% positive predictive value (95% CI 55.0-91.3), 100% negative predictive value (95% CI 90.9-100), LR+ 10.0 (95% CI 3.93-16.13), and LR- 0 (95% CI 0-0.34). Intra rater and inter-rater agreement were 94% ($p < 0.001$) and 93% ($p < 0.001$) respectively[14].

Approved[2] our results and stated that The 3D MSV Doppler is a useful adjunctive tool to the 3D power Doppler or color Doppler to refine the diagnosis of MAP Fifty pregnant women at ≥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 sonographic findings to detect the accuracy of the 3D MSV Doppler in the diagnosis of MAP. 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[2].

Also,[15] study agreed the use of 3D power Doppler with both 2D-US and color Doppler as complementary techniques could improve the antenatal diagnosis or exclusion of morbidly adherent placenta. All patients fulfill the inclusions criteria: gestational age > 28 weeks, previous one or more cesarean delivery, previous uterine surgery, placenta previa, vitally stable patient and women accepted to participate in the study were included. All patients were evaluated using 2D-US, color Doppler and 3D-PD before delivery. The final diagnosis was established by laparotomy and by histopathology of hysterectomy sample if hysterectomy would be done. One-hundred fifty patients were enrolled in the study. 2D-US has higher sensitivity (86.96%) than 2D color Doppler (84.06%) and 3D-PD (79.71%) in the diagnosis of placenta accreta. On the other hand, 3D-PD has slightly higher specificity (83.95%) than color Doppler (82.72%) and 2D-US (77.78%) in the diagnosis of placenta accreta. The most sensitive parameter in 2D-Us was the loss of retroplacental sonolucent zone (86.96%). As regards color Doppler, the most sensitive parameter was the hypervascularity of the uterine-bladder interface (84.06%). Tortuous vascularity with chaotic branching was the most sensitive parameter in 3D-PD with a sensitivity of 82.61%[15].

Clinical implications: In a previous studies, the number of colored voxels correlated with the number of vessels[8]. Similarly, increasing the number of vessels increased the value of VI[8]. This is in agreement with an in-*vivo* study findings where VI also correlated positively with micro vessel density count as assessed by immunohistochemically techniques.[19]. While VI measures the number of color voxels within the placental volume thus indicating the number of vessels, FI measures their intensity of the flow at the time of 3D sweep[9]. This may explain the lack of change in the FI parameter. Since VFI is a multiplication of VI and FI, VI appears to be the most useful parameter in predicting MAP and sMAP[9]. Clinically, the use of VI can detect a number of cases with invasive placentation that the conventional 2D ultrasound cannot, which allows for a better preparation for surgery.

CONCLUSION

In this study, our results showed that the 3D color Doppler VI ≥ 16 predicted the diagnosis of MAP with a 100% sensitivity ,100% specificity which are better than those of 2D ultrasound (60.0% and 89.1% respectively). Sever MAP occurred in 51.2% of MAP and 3D color Doppler of VI > 33.1 predicted sever MAP with a sensitivity of 73.9% and specificity of 86.4%, which was superior to 2D ultrasound. In the current study the sensitivity and the specificity of 2D ultrasound for the diagnosis of MAP was 60.0% and 89.1% respectively when at least one abnormal parameter was present. The sensitivity and specificity dropped to 69.6% and50.0% respectively when severe MAP was the outcome.

CONFLICT OF INTERESTS

There are no conflicts of interest.

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