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

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Abstract

Objective: The study's objective was to assess the accuracy of using prenatal 3-dimensional power Doppler analysis of vascular placental indices to accurately diagnose morbidly adherent placenta objectively. **Background:** Traditionally, 2D ultrasound was used for the diagnosis of a suspected morbidly adherent placenta (MAP) previa. More objective techniques like 3D power Doppler haven't been well studied. **Study Design:** A prospective cohort study is designed for women with gestational age between 28 and 32 weeks with suspected placenta previa. Patients were examined by 2D ultrasound which was used in management decisions. 3D Power Doppler's VI, FI and VFI were measured during the same examination after manual tracing of placenta; data were blinded to obstetricians. Histopathology was performed to confirm MAP. **Results:** Our results showed that the 3D power Doppler VI ≥ 16 predicted the diagnosis of MAP with 100% sensitivity, 100% specificity which is better than those of 2D ultrasound. While VI > 33.1 measured by 3D Doppler predicted severe MAP with a sensitivity of 73.9% and specificity of 86.4%, which was superior to 2D ultrasound. **Conclusion:** In patients with placenta previa, the 3D Doppler's vascular index accurately predicts MAP. Furthermore, vascular and vascular flow indices of 3D Doppler were more predictive of severe cases of MAP compared to 2D ultrasound.

Keywords

3D Color Doppler, 2D Ultrasound, Placental Vascular Indices, Morbidly Adherent Placenta, Placenta Previa

1. Introduction

Normally, the placenta attaches to the wall of the uterus, however, sometimes the placenta invades deeply into the uterine wall that part or all of the placenta remains attached [1]. Recently, the term "morbidly adherent placenta" (MAP) has been more frequently used to describe abnormal implantation of the placental villi into the uterine wall [2]. It is histopathological term-occurs when the placenta fails to detach from the wall of the uterus due to abnormal implantation at the basal plate [3].

Approximately 1 out of every 533 pregnancies, according to the American College of Obstetricians and Gynecologists (ACOG) experience placenta accrete, percreta or increta [3]. The difference between percreta, increta or accreta which are the pathological types used to describe placental invasion, is determined by how deep the placental villi invade into the uterine wall [4] [5] [6].

There is a systematic review showed a wide heterogeneity in terminology used to describe the grades of accreta placentation using the 2D parameters. The authors concluded that the evaluation of the accuracy of ultrasound imaging in screening and diagnosing placenta accreta is limited [5]. In the same review, when combining all cases of placenta accreta, increta and percreta, the loss of sonolucency was the most common finding [5].

Several studies used the 3D color Doppler techniques to diagnose MAP and reported a sensitivity ranging between 39% and 100% based on abnormal vascular patterns [7] [8]. In these studies, the placenta was assessed subjectively for abnormal vascularity using the 3D power Doppler technique without any quantification. Shih *et al.* made the diagnosis of placenta accreta when intraplacental hyper vascularity, inseparable cotyledonal (fetal) and intervillous (maternal) circulations, or tortuous vascularity was noted [7]. Hyper vascularity of the uterine serosa-bladder wall interface and tortuous confluent vessels across the placental width were used as diagnostic criteria for morbidly adherent placenta by Collins *et al.* [8].

A recent study quantified the amount of vessels involved in the diagnosis of morbidly adherent placenta [9]. 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 [9]. 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 [10].

2. Aim of the Work

The study's objective was to assess the accuracy of prenatal 3-dimensional power Doppler to predict the morbidly adherent placenta objectively.

3. 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 using Voluson E8 GE system equipped with 4 - 8 MHz transducers. Uniform diagnostic criteria were applied to diagnose the suspected MAP using at least one of the following findings:

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

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

3) 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 [2].

Pregnant women with at least one identified 2D findings, underwent an additional imaging using 3D power Dopplertrans abdominal ultrasound of the placenta. After full bladder confirmation, obtained using a GE Voluson E8 RAB4-8 transducer probe this technique was previously described for evaluation of placental vascularity [11] [12].

The study was approved by the Ethical Committee of Faculty of Medicine, Ain-Shams University. Verbal consent is taken from all the enrolled patients after explaining the aim of the study and was voluntarily participated when it was clear that it was an observational study that has no harm to them or to their babies.

The placental images were optimized for every patient to visualize the maximum thickness of the 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 30° angle increments to include the maximum viewed placenta. The vascularization index (VI; which is calculated by dividing colored/total voxels, voxels are the cubes that occupy the volume of interest, which is in this case the placenta), the flow index (FI; the average of the color value of all blood flow or the mean intensity of the colored voxels), and the vascular flow index (VFI; is obtained by multiplying VI and FI and dividing the result by 100) which is calculated using the same software. 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 results were blinded too to the sonographer performing

the 3D examination and calculating VI, FI and VFI.

All patients were delivered by caesarean section followed by hysterectomy (cesarean hysterectomy) as planned by the operative physician-based on combination of suspected diagnosis from 2D ultrasound and clinical assessment which were used as tools to make the decision before surgery.

If 2D findings were not suggestive of MAP, hysterectomy was performed when the placental invasion was obvious with increased vascular markings and visualization of placenta through the uterine window, when the placenta failed to separate spontaneously or when there is resistance to manual placental separation with or without hemorrhage 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 histo-pathologist.

The patients were divided according to the collected data into 2 groups (group A and group B).

➤ Group (A): patients without MAP.

➤ Group (B): patients with MAP confirmed by histopathological examination of hysterectomy specimen and according to this examination they were sub grouped into MAP and severe MAP.

Severe MAP (sMAP) which was identified for this study by the presence of the following components:

+ Increta or percreta placenta on histopathology.

+ Transfusion of ≥ 2 units of PRBCs and estimated blood loss > 2000 ml.

+ Blood loss > 2000 ml was considered severe based on previous reviews [13] [14].

4. Statistic Analysis Method

Descriptive statistics were done for quantitative data as minimum & maximum of the range as well as mean ± SD (standard deviation) for quantitative normally distributed data, median and 1st & 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.

K values > 80% were considered very good agreement [15]. Post hoc Bonferroni test was done to find homogenous groups in significant tests among more than two independent groups. ROC curve used to assess the performance of different tests and differentiate between certain groups. The level of significance at

p value < 0.050 considered significant, otherwise results is non-significant.

5. Results

100 pregnant patients were included in our study (**Figure 1**). All cases were delivered by C.S 97% of them underwent LUS C.S. Among MAP group 6 cases suffered from visceral injuries and 2 cases were admitted to the ICU with mean estimated blood loss of 2.4 ± 1.3 L (**Table 1**).
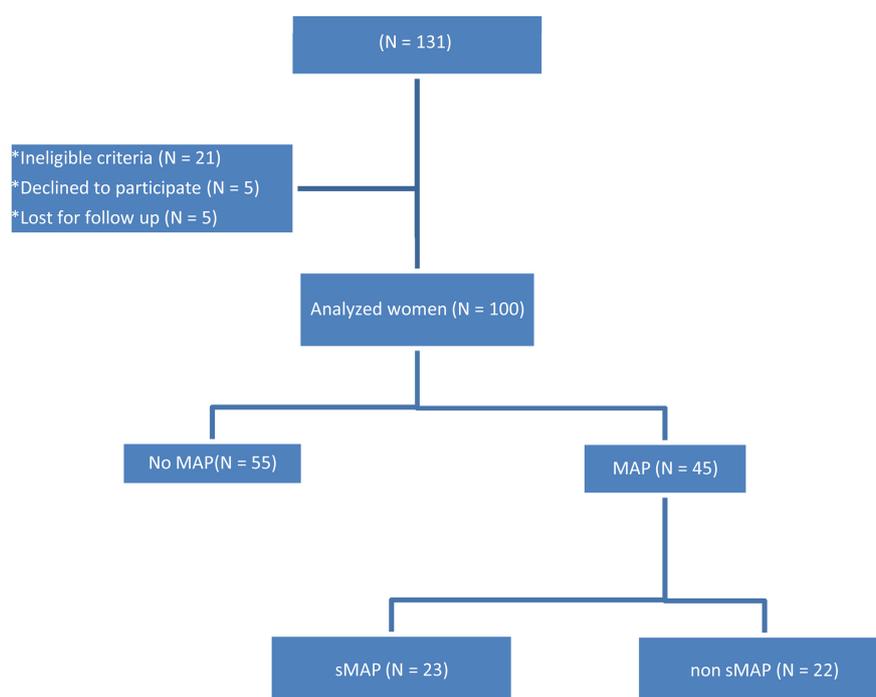

Figure 1. Flow chart of the studied cases.

Table 1. Characteristics and outcomes in MAP vs. no MAP.

Characteristics	MAP (N = 45)	No MAP (N = 55)	p
Age (years)	30.8 ± 7.0	31.2 ± 4.0	^0.751
GA at investigation (weeks)	33.8 ± 3.0	34.8 ± 1.1	^0.100
GA at delivery (weeks)	35.1 ± 2.8	35.9 ± 1.0	^0.092
Parity	3.0 (2.0 - 4.0)	3.0 (2.0 - 3.0)	✡0.643
Previous CD	2.0 (1.0 - 3.0)	1.0 (0.0 - 3.0)	✡**0.002***
HTN	4 (8.9%)	1 (1.8%)	§0.171
DM	0 (0.0%)	1 (1.8%)	§1.000
DC	6 (13.3%)	1 (1.8%)	§**0.043***
Myomectomy	2 (4.4%)	0 (0.0%)	§0.200
Blood loss (L)	2.4 ± 1.3	0.8 ± 0.3	^**<0.001***
Blood transfusion	(2 - 12 unit)	(1 - 2 unit)	<0.01
Intra-operative injuries	6	1	<0.01
ICU admission	2	0	<0.01

^Independent t-test. ✡Mann Whitney test, #Chi square test. §Fisher's Exact test. *Significant, GA; gestational age, DM: diabetes mellitus, HTN: hypertension, DC: dilatation and curettage, ICU: Intensive care unit.

Of 33 cases were clinically diagnosed with MAP based on 2D parameters before the delivery even; 27 patients 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 severe uncontrollable intraoperative bleeding).

And of 67 cases 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, 45 cases (95.74%) had confirmed MAP based on the histopathological examination of the hysterectomy specimen; 21 were accreta, 13 increta, and 11 percreta.

5.1. Prediction of MAP Using 3D Doppler Indices

Figure 2 and Figure 3 illustrate 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 2; p < 0.001 both). FI values were similar in both groups, ROC curve was 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 4). Among the 3D Doppler indices, VI had the highest AUC and FI had the lowest (Table 2, Figure 4) VI ≥ 16 predicted
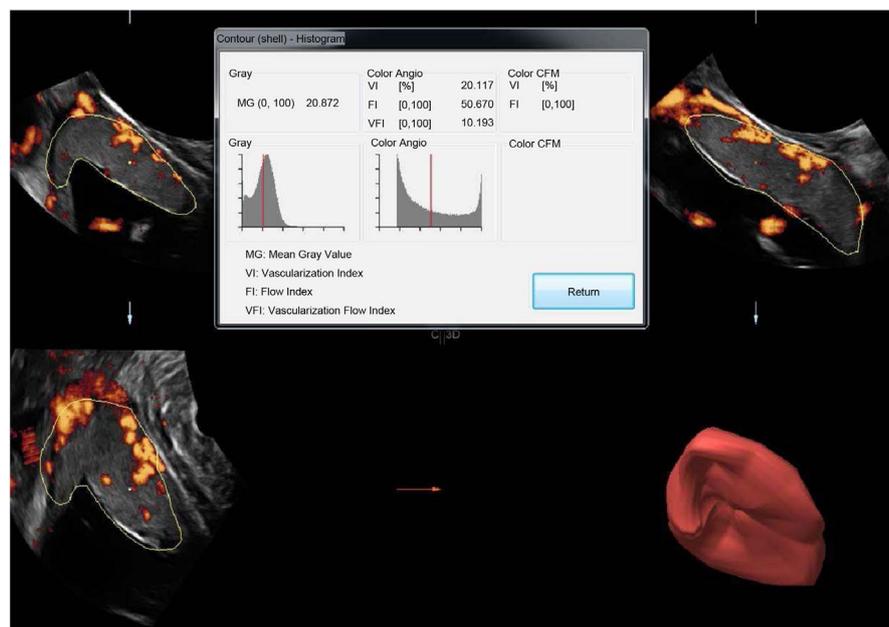

Figure 2. Manual tracing of placental volume at a 30° angle and calculation of vascular (VI), flow (FI), and vascular flow (VFI) indices.
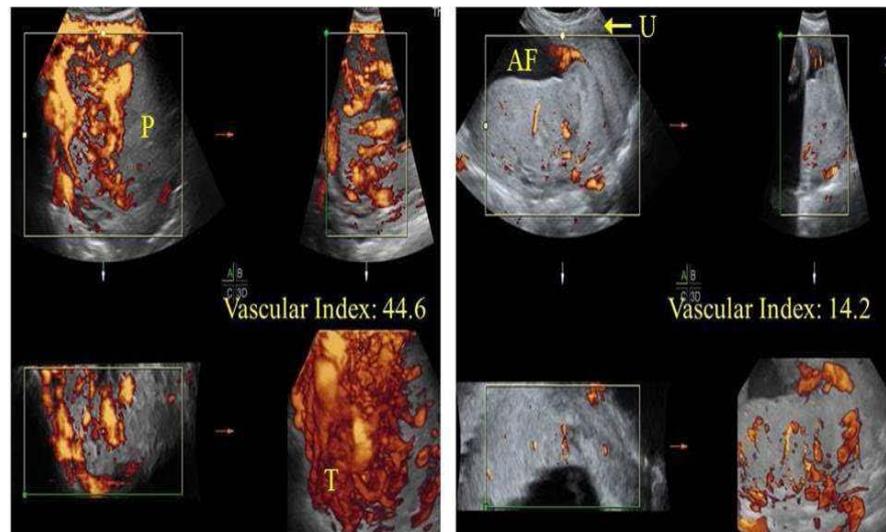
Figure 3. Ultrasound comparison of 3D Doppler placenta between MAP with percreta (left) and No MAP (right), P, placenta; AF, amniotic fluid; U, uterine wall; T, tortuous vessels.
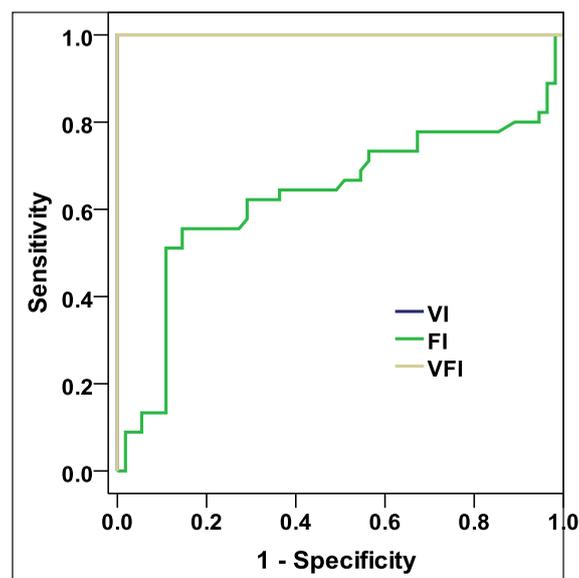
Figure 4. ROC curve in the prediction in differentiating MAP from non-MAP (VI and VFI are overlapping).

the diagnosis of MAP with a 100% sensitivity and 100.0% specificity (Table 4).

Table 2(a) and Figure 4: 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.

5.2. Prediction of Severe MAP (sMAP) Using 3D Doppler Indices

sMAP was found in 23/45 (51.2%) patients. The mean of calculated blood loss volume was on average 3.5 ± 0.9 L. The placenta pathology in the sMAP was 7 increta and 11 percreta.

Table 2. AUC: Area under curve, SE: Standard error, CI: Confidence interval, *significant. (a) MAP vs. no MAP. (b) MAP vs. non s MAP.

(a)

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

(b)

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

Similarly, using VI, FI, and VFI measured by 3D power Doppler for the prediction of severe MAP. VI of more than 33.1 predicted sMAP with a sensitivity of 73.9% and 86.4% specificity (Table 3).

ROC curve was used to evaluate the ability VI, FI, VFI to predict (sMAP) and an (AUC) was calculated for each parameter (Table 2, Figure 5). Among the 3D Doppler indices, VI had the highest AUC and VFI had the lowest (Table 2).

Table 2(b) and Figure 5: Only VI had significant moderate diagnostic performance in differentiating sMAP from non-sMAP.

Table 3 shows that: VI ≥ 33.1 had highest diagnostic characteristics in differentiating sMAP from non-sMAP.

5.3. Comparing 2D Findings and 3d Findings

Comparison between 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 Table 3 and Table 4. 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 ≥ 33.1 is used. Similar increases were seen with VFI. However, we found that FI was not increased in association with MAP.

Table 4: 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.

6. Discussion

The incidence of MAP has continued to rise primarily due to the increase in

Table 3. 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.

Table 4. Diagnostic characteristics of 2D and 3D in differentiating MAP from no 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.
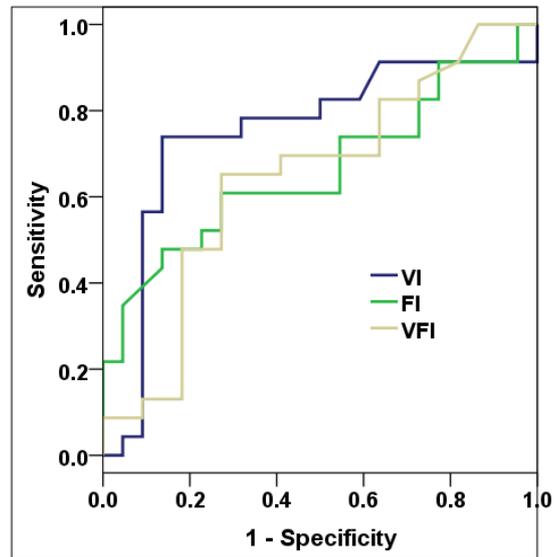
Figure 5. ROC curve in differentiating sMAP from non-sMAp.

cesarean delivery rates with an overall incidence of approximately 1 in 533 pregnancies [3]. MAP can result in major maternal morbidities such as life-threatening hemorrhage and intra-operative organ injuries [16]. Therefore, it is important to be able to detect this entity antenatally with high reliability to allow for a proper preparation for delivery in an appropriate unit equipped to handle potentially complicated surgery [17] [18].

The diagnosis of MAP has traditionally been suspected on 2D ultrasound and color Doppler. Although how the color Doppler findings should be used is subjective and the published descriptions of exactly what findings are predictive of MAP are not specific, Color Doppler of vascular patterns in the placenta and MRI may also be helpful in establishing the diagnosis [2].

Despite these reported findings, the diagnosis of MAP remains as a subjective diagnosis per the interpretation of the observer [8]. Additionally, there are limited previously published studies available for 2D to determine the severe form of MAP that is associated with massive hemorrhage, percreta or increta, and intensive care admission.

During the last few years, three-dimensional (3D) power Doppler technique was introduced as a tool to diagnose MAP based again on the observer's interpretation of 3D images. The objective of our study was to analyze the ability of gray-scale two-dimensional (2D) ultrasound vs. 3D power Doppler vascular and flow indices to objectively predict MAP and severe MAP. We hypothesized that the calculation of 3D power Doppler indices can accurately predict MAP and severe MAP.

6.1. Findings and Interpretation

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 with a 100% sensitivity and 100.0% specificity. Furthermore, the indices are higher when the clinical severity is increased. The sensitivity of 73.9%, 86.4% specificity and the negative predictive value in predicting sMAP was 90.7% 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.

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% and 50.0% respectively when severe MAP was the outcome.

There is a significant difference in the ability of prenatal prediction of MAP and sMAP between 2D ultrasound and 3D power Doppler which state that the 3D power Doppler is a more accurate diagnostic tool of MAP than traditional 2D ultrasound.

6.2. Comparison with Previous Studies

Previously reported studies to diagnose MAP by 2D ultrasound have concluded a range between 76% - 94% and 74% - 99% for sensitivity and specificity respectively [2] [18] [19] [20]. This wide range is probably attributed to the subjectivity of the 2D parameters and the variation in sample size.

Another factor that affected this range was the review by a single examiner. When multiple examiners blindly reviewed every ultrasound examination, the sensitivity and the specificity were found to be even lower (63% and 87% respectively) [21]. There was a systematic review showed a wide heterogeneity in terminology used to describe the grades of accreta placentation using the 2D parameters [22]. The authors concluded that the evaluation of the accuracy of ultrasound imaging in screening and diagnosing placenta accreta is limited [22].

All these factors were avoided in our study by using the latest and the most accurate description of 2D findings, considerable sample size and the examination was reviewed by single examiner for 2D ultrasound and another for 3D power Doppler.

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 [8] [23] [24]. In these studies, the placenta was assessed subjectively for abnormal vascularity using the 3D power Doppler technique without any quantification.

Another study quantified the amount of vessels involved in the diagnosis of morbidly adherent placenta [9]. 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 [9]. Although abnormal vascularity of the

utero-placenta 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. While in our study the placenta was traced manually with examination of vascularity of placenta and utero-vesicle space and at the maximum placental thickness using offline analysis of an optimized 3d Doppler images and the vascular indices were measured to decrease the percentage of subjective operator's error.

In Abdel Moniem *et al.* [25] study on 50 pregnant patients with suspected MAP, using both 2D US and 3D Power Doppler scans to assess the best parameter that could predict MAP prenatally. The results show that the best 2D parameter was disruption of uterine serosal interface (81.8 sensitivity), so could be used in screening for MAP and the best parameter for confirmation of MAP diagnosis was presence of exophytic mass invading the bladder with 94.9% specificity.

While the best 3D power Doppler parameter detected was disruption of uterine serosal interface (90.9 sensitivity and 68.8% specificity). this study offer the 3D power Doppler as a complementary tool to 2D us in diagnosis of MAP which is not in line with our study that present 3D power Doppler as separate accurate diagnostic tool with definitive criteria that is not subjective to the interpretation of the examiner.

The same concept was used in the study conducted by Hussein *et al.* which also agreed to 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, but ended with the same subjective findings that could easily misinterpreted by sonographers.

While in Haidar *et al.* [10] study conducted to 50 women examined using 2D US and 3D power Doppler that measures placental vascular indices using VOCAL software applied to analyze offline placental images. it stated that vascular index of more than 21 accurately predicts the morbidly adherent placenta in patients with placenta previa with a sensitivity and specificity of 95% and 92% respectively, which is similar to our results but MAP was predicted at VI ≥ 16 which have better sensitivity and specificity values (100% both) In addition, compared to 2D ultrasound; 3D Power Doppler vascular (more than 31) and vascular flow indices were more predictive diagnostic tools of severe MAP with a sensitivity of 100% and specificity of 90%. As for our results it shows a higher cut off value of VI to predict sMAP (≥33.1) with much less sensitivity of 73.9% and less specificity of 86.4. But this study has a low sample size of 50 cases which is not enough to generalize the results and used VOCAL software offline analysis of placental images of maximum placental thickness using 4D view ,such technology is not available to all maternity centers. Despite the differences between this study and our study both concluded 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.

6.3. Clinical Implications

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.

Despite the limitations, the major strength of our study is the objective nature of the 3D Doppler technique for the diagnosis of MAP. The technique has a short learning curve and is reproducible. It has the potential to reduce the variation between examiners and increase the rate of antenatal detection of MAP leading to a decrease in maternal and fetal morbidities.

6.4. Weaknesses and Strengths

The small sample size is one of the limitations of our study. In addition, only women with placenta previa were included as we considered this a risk factor for MAP that would allow us to have a better yield for this disease in our study population. MAP may also occur in women without placenta previa; however our study did not address this population. Our study period was limited to an interval of gestational age of 28 - 32 weeks and diagnosing the condition prior to 28 weeks gestation needs to be studied further. We also could not adjust for other factors such as the number of previous CD due to the sample size. Additionally, 3D color Doppler volume studies are currently available only in the GE Voluson machines.

This may not apply to other technologies and with changing technology the indices may change for the diagnosis, which will need to be revalidated. Our study did not assess MRI ability to predict MAP in comparison to 3D Doppler indices. However, MRI is more expensive and less readily available.

Despite the limitations, the major strength of our study is the objective nature of the 3D Doppler technique for the diagnosis of MAP. The technique has a short learning curve and is reproducible. It has the potential to reduce the variation between examiners and increase the rate of antenatal detection of MAP leading to a decrease in maternal and fetal morbidities.

7. Conclusions

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).

Severe MAP occurred in 51.2% of MAP and 3D color Doppler of VI > 33.1 predicted severe 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 were 60.0% and 89.1% respectively when at least one abnormal parameter was present. The sensitivity and specificity dropped to 69.6% and 50.0% respectively when severe MAP was the outcome.

Future Research Implications

3D power Doppler is introduced as an objective technique that may limit the variations in diagnosing MAP due to the subjectivity of 2D ultrasound interpretations. So, a multi-center prospective study is needed to validate our findings, and confirm the usefulness of this methodology and its ability to improve the prenatal diagnosis of this condition compared to 2D ultrasound before an appropriate clinical application is determined.

Other available imaging technologies such as placental elastography and 3D MSV Doppler should be assessed to measure these indices with a larger sample size to design definitive prenatal diagnostic measures of MAP to decrease maternal and fetal morbidity and mortality.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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