Introduction
Morbidly adherent placenta (MAP) presents a significant obstetric challenge, at times resulting in life-threatening bleeding and/or peripartum hysterectomy [1]. Once a rare diagnosis, MAP now complicates as many as one per 533 pregnancies [2].

The increasing rate of cesarean deliveries (CDs) correlates with the rising incidence of MAP [3]. Placenta accreta is not exclusively a consequence of CD, but much smaller surgical damage to the integrity of the uterine lining, such as those following uterine curettage, manual delivery of the placenta, postpartum endometritis, and previous hysteroscopic surgery, has been associated with abnormal placentation in subsequent pregnancies [4].

The diagnosis of MAP involves a number of different ultrasound (US) variables, some qualitative and others that have been quantified. These markers include an inability to visualize the normal retroplacental clear zone, irregularity and attenuation of the uterine-bladder interface, retroplacental myometrial thickness, presence of intraplacental lacunar spaces, and bridging vessels between the placenta and bladder wall when using color Doppler [1].

Objective
The aim of this study was to assess the value of adding three-dimensional (3D) ultrasound (US) power Doppler vascular indices (as a diagnostic technique) to gray-scale technique for antenatal diagnosis of placenta accreta.

Background
Abnormal invasive placentation represents obstetric challenge that is associated with catastrophic hemorrhage. Varied terminologies have been applied to this condition; however, the recent guidelines suggested placenta accreta spectrum, which includes accreta, increta, and percreta.

Patients and methods
Evaluation of 100 pregnant patients with placenta previa was done. They had a mean age of 33.3 years. All patients were subjected to two-dimensional US and 3D power Doppler vascular indices US at gestational age between 28 and 34 weeks, before elective cesarean delivery.

Results
Of the 100 patients, 62 (62%) patients were proved to have abnormal placental invasion based on pathological outcome and 38 (38%) patients had conservative surgical management. The sensitivity of 3D power Doppler parameters was 96.6% for intraplacental hypervascularity, 88.7% for torturous vascularity and 88.7% for basal vessels involving bladder. Regarding the vascular indices, for vascularization index, sensitivity was 67.7%; for flow index, sensitivity was 48%; for vascular flow index, sensitivity was 87%; and for Virtual Organ Computer-aided Analysis (placental volume), sensitivity was 87%. In comparison, regarding the two-dimensional US parameters for diagnosis of placental invasion, for absence of sonolucent areas, sensitivity was 67.7%, for myometrial thickness less than 1 mm, sensitivity was 79%, for number of lacunae more than 4, sensitivity was 67.7%, and for presence of vascularity between placenta and cervix, sensitivity was 74%.

Conclusion
Combining 3D power Doppler to gray-scale and color Doppler US was more predictive of abnormal placental invasion.

Keywords:
antenatal diagnosis, color Doppler ultrasound, placenta accreta, placenta previa, ultrasound power Doppler
Antenatal diagnosis of placental invasion has the potential to improve maternal and fetal outcomes. Predelivery knowledge of MAP allows for multidisciplinary planning and delivery before the onset of labor and/or vaginal bleeding [5]. The aim of this study was to assess the diagnostic accuracy of two-dimensional (2D) US versus three-dimensional (3D) power Doppler for prenatal diagnosis of placenta accreta.

Patients and methods
This prospective observational study was conducted at the Department of Obstetrics and Gynecology, Menoufia University Hospital, and Feto-Maternal Unit, Department of Obstetrics and Gynecology, Cairo University Hospital, Egypt, from April 2017 to March 2019 in women with singleton pregnancies, between 28\(^0/7\) and 34\(^0/7\) weeks of gestation. The study protocol was formally reviewed and approved by the Medical Ethics Committees at both Menoufia and Cairo, Faculties of Medicine. Women were referred for US for the evaluation of placenta previa and signs of abnormal placental invasion.

A total of 110 pregnant patients between 28 and 34 weeks with a history of previous one or more cesarean sections diagnosed with placenta previa were included in the study.

The patients gave written consent before the study. Patients with medical disorders such as bleeding disorders, hypertension and diabetes mellitus, lethal fetal anomalies, and emergency surgery were excluded. All the patients included were examined using 2D gray-scale US and 3D power Doppler. The 110 enrolled patients were routinely followed up afterward and were admitted for surgery according to local protocols. Overall, two patients decided to withdraw, seven patients had an emergency delivery, and one patient had congenital cardiac malformation and were excluded. The remaining 100 patients were enrolled into the study with routine follow-up afterward, and admission for surgery was done according to local protocol. The following was done before surgery:

**Antenatal diagnosis**
This starts by complete history taking with special emphasis on the nature of previous cesarean sections or uterine surgeries, history of hematuria or vaginal bleeding, followed by general and obstetric examination.

**Scan technique**
US examinations were performed by certified sonographers, using GE E10 device (Hatfield, UK). First abdominal US was done with the patient having a full bladder to evaluate the signs of placental invasion. Gray scale, color Doppler, power Doppler, and 3D power Doppler were applied.

Then the patient was instructed to evacuate the urinary bladder, and gray-scale abdominal US is repeated to confirm placental location as well as perform fetal biometry to assess gestational age and estimate fetal weight.

Analysis of the angioarchitecture of the lower uterine segment and the placenta with 3D power Doppler targeted to this region was done. 3D volumes were obtained in automatic sweeps using a motorized curved-array transducer while the women held their breath.

Two views were evaluated: the lateral view to observe the intraplacental vasculature and serosa – bladder complex along the sagittal axis of the maternal pelvis, and the basal view illustrated the serosa – bladder interface in a 90° rotation of the lateral view observing from the direction of the bladder.

The scanning of the placental vascular tree was performed with the use of 3D static power Doppler (scanning angle 85°, Quality: high, Speckle Reduction Imaging II3) in the absence of fetal and maternal movements. Only entire scanned placenta were included in the study.

The following settings of the Virtual Organ Computer-aided Analysis II program were used to measure the volume of the placenta: manual trace and rotation angle 30° (Fig. 1).

**Figure 1**

![Manual tracing of placental volume at a 30° angle and calculation of vascularization index (VI), flow index (FI), and vascular flow index (VFI).](http://www.mmj.eg.net)
Finally, the 3D power Doppler volume histogram program automatically calculated the values of vascularization index (VI), flow index (FI), and vascular flow index (VFI) within the obtained volume [6].

VI is the proportion of colored/total voxels (voxels being the cubes that occupy the volume of interest, which is in this case the placenta); FI is the mean color value of all blood flow or the average intensity of the placenta), and VFI is 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 (Fig. 1) [7].

Afterward, transvaginal US using gray-scale, color, and power Doppler techniques was done to further evaluate the lower segment and cervix. The following sonographic criteria were evaluated and recorded for each patient: gray-scale parameters include placental location (anterior, posterior, and lateral), absence of retroplacental hypoechoic zone, presence of four or more placental lacunae, and myometrial thickness less than 1 mm.

2D power Doppler and color Doppler showed the following: length of vascularization across placental bladder interface in cm; vascularity between the placenta and the cervix, present or absent; and number of bridging vessels between placenta and bladder serosa.

3D power Doppler showed the following: intraplacental hypervascularity, tortuous vascularity with ‘chaotic branching,’ and basal view revealing vessels involving the serosa – bladder interface.

Final diagnosis of MAP was made based on the pathological examination of hysterectomy specimen by a perinatal pathologist, which included the presence of accreta, increta, or percreta.

All biopsies were fixed in 4% formaldehyde in PBS and embedded in paraffin. Paraffin sections that were 4 mm thick were mounted on aminopropyl triethoxysilane (Tespa)-coated (Messmikroskope, Germany) glass slides [8].

Statistical analysis
It was conducted by statistical package of the social science (SPSS) version 20 (SPSS Inc., Chicago, Illinois, USA). Quantitative data were expressed as mean ± SD and analyzed applying Student t-test. Qualitative data were expressed as number and percentage. P value of less than 0.05 was considered statistically significant.

Results
Mean age of patients at the time of scan was 33.3 ± 4.5 years, mean parity was 3.2 ± 0.9, and mean BMI was 30.07 ± 2.5, mean number of previous cesarean sections was 2.4 ± 1.08 and mean gestational age was 33.5 ± 1.4 weeks (Table 1).

Regarding the accuracy of 2D US parameters for diagnosis of placenta accreta, for absence of sonolucent areas, sensitivity was 67.7%, specificity was 73.6%, positive predictive value (PPV) was 80.7%, and negative predictive value (NPV) was 58.3%; for myometrial thickness less than 1 mm, sensitivity was 79%, specificity was 60%, PPV was 77.7%, and NPV was 63.8%; for number of lacunae more than 4, sensitivity was 67.7%, specificity was 77.7%, PPV was 56.5%, and NPV 66%; and for presence of vascularity between placenta and cervix, sensitivity was 74%, specificity was 81.5%, PPV was 86.7%, and NPV was 65.9% (Table 2).

Regarding the accuracy of 3D US parameter for prediction of placenta accreta, for intraplacental hypervascularity, sensitivity was 96.6%, specificity was 81%, PPV was 89%, and NPV was 93%; for tortuous vascularity, sensitivity was 88.7%, specificity was 78.9%, PPV was 87%, and NPV was 81%; and for basal vessels involving bladder, sensitivity was 88.7%, specificity was 78.9%, PPV was 83.3% and NPV was 81%. Regarding vascular indices, for VI, sensitivity was 67.7%, specificity was 89%, PPV was 91%, and NPV was 93%; for FI, sensitivity was 48%, specificity was 77.7%, PPV was 93%, and NPV was 65%; for VFI, sensitivity was 76.9%, specificity was 76.9%, PPV was 85% and NPV was 78%; and for Virtual Organ Computer-aided Analysis (placental volume), sensitivity was 87%, specificity was 76.9%, PPV was 85%, and NPV was 78% (Table 2).

Regarding the pathological finding of the space after hysterectomy, 28 (47%) of cases were accreta, 21 (33%) were increta, and 13 (20%) were percreta (Table 3).

Discussion
The overall maternal age at delivery was 33.3 ± 4.5 years, with a mean gestational age of 33.5 ± 1.4 weeks, and all
cases had at least one prior CD. The mean number of previous cesarean sections was 2.4 ± 1.08, and no other uterine surgeries were reported. The most common placental location was anterior (90%).

Among the 2D US parameters, for myometrial thickness less than 1 mm, the sensitivity was 79%, specificity was 60%, PPV was 77.7%, and NPV was 63.8%, and for presence of more than four lacunae, sensitivity was 67.7%, specificity was 77.7%, PPV was 56.5%, and NPV was 66% for prediction of placental invasion compared with previous studies. Horowitz et al. [9] reported a range of sensitivity between 22 and 100%, Shawky et al. [10] reported sensitivity of 67%, specificity of 100%, and PPV of 100%. Wong et al. [11] and Abdel Magied et al. [12] reported sensitivity of 54.5%, specificity of 100%, PPV of 100%, and NPV of 70.5% for myometrial thickness less than 1 mm.

Haidar et al. [13] reported sensitivity of 82.6%, specificity of 88.9%, PPV of 85.5%, and NPV of 85%. Moniem et al. [14] reported sensitivity of 73.9%. Antonio et al. [15] reported sensitivity to detect placenta accreta was 77.43% and specificity was 95.02%. Cali et al. [16] reported sensitivity of 73% specificity of 86%, PPV 60%, and NPV 90%. Shih et al. [17] reported a sensitivity rate of 74% for presence of four or more lacunae.

When the 3D parameters were used for prediction of MAP, the following was reported: the intraplacental hypervascularity sensitivity detected by 3D power Doppler was 96.7%, specificity was 81%, PPV 89%, and NPV 93%, compared with other studies. Cali et al. [16] reported sensitivity of 39%, specificity of 100%, PPV of 100% and NPV of 85%. Abdel Moniem et al. [14] reported sensitivity of 79.9%, specificity of 71%, PPV of 73% and NPV of 82%. Shih et al. [17] reported sensitivity of 89%, specificity of 92%, PPV of 93%, and NPV of 89%.

When the 3D Doppler indices were performed, the mean values of VI, VFI, and PV were significantly higher in the patients with confirmed MAP, with P values of 0.000, 0.001, and 0.001, respectively (Table 4).

The ROC curves were constructed to assess the ability of the VI, FI, VFI, and Per vaginal (PV) to predict a MAP, and an area under the curve (AUC) was calculated for each parameter. VI had the highest AUC of 0.99 (95% CI: 0.97–1.00) and FI had the lowest (AUC: 0.45; 95% Confidence interval (CI): 0.33–0.57).

The VI of at least 18 predicted the diagnosis of MAP with a 67.74% sensitivity, 89% specificity, 91% PPV, and 93% NPV. These results are in contrast to the only mentioned study by Haidar et al. [13]. Among the 3D Doppler indices, VI had the highest AUC of 0.99 (95% CI: 0.97–1.00) and FI had the lowest (AUC: 0.46; 95% CI: 0.18–0.55). The VI of at least 21 predicted the diagnosis of MAP with 95.1% sensitivity. The differences in results may be related to the technique used for measurement and small sample size used in Haidar et al. [13].

All patients were delivered by CD. Overall, 62% of the cases underwent a cesarean hysterectomy and
References

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Conflicts of interest
There are no conflicts of interest.

Conclusion

According to this study, 3D power Doppler can be used as a complementary technique for confirmation of the diagnosis of placental invasion owing to its high sensitivity.

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were confirmed MAP by histopathology, where 28 (46%) were accreta, 21 (34%) increta, and 13 (20%) percreta, and the remaining 38 cases had a CD without hysterectomy.

Visceral injury reported in the study were 19 cases of bladder injury and only one case had ureteric injury. Overall, 19 cases of bladder injuries of the 100 patients with confirmed intraoperative abnormal placental invasion were diagnosed and managed intraoperatively. The 15 cases of bladder injuries occurred during cesarean hysterectomies. Three cases were accidental and one was intentional cystotomy to facilitate bladder dissection without injury to the bladder trigon. Only one case had ureteric injury in lateral broad ligament invasion with placenta; this rate was lower than that mentioned Rezk and Shawky [18]. Reported incidence of bladder injury was ~29.7% and ureteric injury was ~18.9%. The marked decline in bladder injury rate is owing to a change in bladder dissection technique.


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