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Original Article

3D Power Doppler versus Grayscale and Color Doppler Sonography in Diagnosis of Placenta Accreta Spectrum. A prospective Observational Cohort Study

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Abstract

Background: Placenta accreta is a major source of maternal morbidity and mortality and is currently the major reason for peripartum hysterectomy.

Objectives: to evaluate the diagnostic performance of 3D power Doppler in the prenatal diagnosis of placenta accreta spectrum disorders versus grayscale ultrasound and color Doppler ultrasonography.

Methods: Evaluation of 202 pregnant women with placenta previa with gestational age 28 to 30 weeks was done. All participants were subjected to Grayscale ultrasound and color Doppler US in addition to 3D power Doppler US before elective cesarean sections were done.

Results: 3D power Doppler US; (VI) predicted severe placenta accrete spectrum disorders with sensitivity of 93.9% and specificity of 77.61%; while (placental volume) predicted it with sensitivity of 96.88% and specificity of 80.60%, 2D color Doppler US; (Lower uterine segment hypervascularity) with sensitivity of 88.24% and specificity of 90.91%, grayscale US; (retroplacental hypoechoic zone) with sensitivity of 73.13% and specificity of 69.63%.

Conclusion: Antenatal ultrasound is the method of choice used to establish diagnosis and direct clinical management. After using 3D power Doppler ultrasonography, better results were obtained; and these were confirmed when compared with intra-operative findings.

Key words: Antenatal diagnosis, color Doppler US, grayscale US, placenta accreta spectrum, power Doppler US

Introduction

The word placenta accreta spectrum disorders (PASD) implies an atypical implantation of the placenta into the uterine wall and has been used to express placenta accreta, increta and percreta. Placenta accreta is a placenta where the placental villi sick on directly to the myometrium. Placenta increta is a placenta where the placental villi attack into the myometrium and placenta percreta is a placenta where the villi invade through the myometrium and into serosa. [1]

No antenatal diagnostic method gives the clinician 100% assurance of either ruling in or ruling out the existence of placenta accreta. The definitive diagnosis of placental accreta spectrum is frequently ended postpartum on hysterectomy specimens when an area of accretion shows chorionic villi which make direct contact with the myometrium and absence of deciduae. [2] Antenatal ultrasound is the method of choice used to establish the diagnosis and direct clinical management. [3] Second and third trimester grayscale 2D sonographic characteristics comprise loss of continuity of the uterine wall, numerous vascular lacunae (irregular vascular spaces) inside placenta, giving "Swiss cheese" look nearby to the placental implantation site, lack of a hypoechoic margin (myometrial zone) between the placenta and the myometrium, bulging of the placental and myometrial location into the bladder. [4] Color Doppler US markers suggestive of PASD include the following: diffuse or focal lacunar flow, vascular lakes with turbulent flow (peak systolic velocity over 15 cm/s), hypervascularity of serosa–bladder interface and markedly dilated vessels over peripheral sub placental zone. [5]

The combined use of power Doppler with three dimensional (3D) ultrasound provides the possibility of quantifying moving blood within a volume of interest. Three indices are calculated, namely vascularization index (VI), flow index

(FI) and vascularization flow index (VFI) [6,7].

The use of a consistent multidisciplinary team (MDT) improves maternal outcomes and can drive internal continuous quality improvement as progressive experience is gained by that same group; Multidisciplinary team consisting of neonatologist, anesthesiologist, urologist, interventional radiologist, vascular surgeon and blood banking physician [8].

Aim of the study

The aim of this work was to evaluate the diagnostic performance of 3D power Doppler in the prenatal diagnosis of placenta accreta spectrum disorders versus grayscale ultrasound and color Doppler ultrasonography.

Patients and Methods

A prospective observational cohort study conducted at Menoufia university and Shebien Elkom teaching hospitals during the period from June 2020 till April 2023.

The study started after getting the official approval of written proposal for it; from the committee of Obstetrics and Gynecology department then approved by the research ethics committee of faculty of medicine (7/2020 OBGN 28).

Sample size: based on past review of literature [9] showed the sensitivity of Doppler in detection of loss of retroplacental clear zone is 87.3%. Sample size has been calculated at 80% power and 95%CI based on Sensitivity = $Z^2_{1-\alpha/2} \times SN \times (1-SN) L^2 \times$ Prevalence where n = required sample size, S= anticipated specificity, α = size of the critical region (1 – α is the confidence level), z1-α/2 = standard normal deviate corresponding to the specified size of the critical region (α), and L = absolute precision desired on either side (half-width of the confidence interval) of specificity. It is estimated that 200 participants with and without accreta were required & 26 participants were added to the calculated sample for chance of any dropped out patients.

Inclusion criteria: pregnant women with GA at 28 to 30 weeks with single, viable fetus with one or more previous CS &

diagnosed by 2D US with anterior placenta previa. Exclusion criteria were; major fetal congenital anomalies, pregnant women with previous history of rupture uterus or with other congenital uterine anomalies or with other uterine scars other than of previous CS, pregnant women with previous urinary bladder, ureteric or bowel injury, Pregnancy complicated by PROM, IUGR, coagulopathy and pregnant women with chronic medical diseases (HTN, DM, Cardiac....etc).

Two hundred two pregnant women met the inclusion criteria; they were diagnosed during their antenatal care as anterior placenta previa using 2D US. At radiology department; Menoufia university hospital; by the same radiologist operator. All women in this study were subjected to full history taking, examination, laboratory investigations and 2D US. Then accordingly all pregnant women included were examined by LOGIQ E10 device using grayscale, color Doppler US and 3D power Doppler US [General Electric Company (GE) is an American multinational company; incorporated in the state of New York and headquartered in Boston] with: Virtual Organ Computer aided Analysis (VOCAL) software at same examination. PASD was confirmed intraoperative. During US scanning by Trans-abdominal Probe; All participants were in supine position with a slightly tilted to left side to avoid aorto-caval compression during scanning & with their urinary bladder partially filled to enhance the resolution of the deeper structures to aid well examination of lower uterine segment, placenta and utero-placental interface.

Grayscale and color Doppler US markers were detected as placental lacunae, presence of lacunar vascular flow, abnormal utero-placental interference, myometrial thinning (<1mm), absence of the retroplacental myometrium, interruptions or irregularities at the level of the utero-vesical interference, lower uterine segment hypervascularity on color Doppler signal observed between the

myometrium and posterior wall of bladder or in the placental tissue at lower uterine segment and/or the cervix (figure 1). An 85˚ angle of acquisition (the maximum that could be acquired) was used and the pregnant women were asked to hold her breath during the acquisition to improve image quality. 3D placental volumes were assessed by manual tracing at 30˚ angle increments to include the maximum viewed placenta [10]. The volume of placenta acquisition was documented (figure 2).

Vascularization index (VI; which was calculated by dividing colored/ total voxels, voxels were the cubes that occupy the volume of interest, which was in this case the placenta), Flow index (FI; the average of the color value of all blood flow or the mean intensity of the colored voxels), Vascular flow index (VFI; was obtained by multiplying VI and FI and dividing the result by 100) which was calculated using the same software. Data was randomized and blindly to participant (single blind). Images were stored and an offline analysis was performed using 4D view setup_ Demo_18Ext3 application, Programme name: (Install script setup launcher)**.** Using the Virtual Organ Computer-Aided Analysis (VOCAL) software (GE Health care Austria GmbH & Co OG). Once the placenta was traced and VOCAL software was applied, results were instantly obtained automatically. 3D Power Doppler indices were measured during the examination and were correlated to intra-operative criteria and were used for sorting degree of severity of PASD.

For all pregnant women participated in this study; their data (prenatal, intraoperative) collected, recorded and statistically analysed.

Ethics Approval

An informed consent was obtained from the mothers on admission to Menoufia university and Shebien Elkom teaching hospitals when needed. All needed official permissions were obtained. The study was approved by ethical committee for research in Menoufia University.

Statistical analysis

Data was analyzed using SPSS (i.e. statistical package for social sciences) program version 20, (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp). Qualitative variables as placenta accrete spectrum, retroplacental hypoechoic zone area….. etc. were described in frequencies while, Continuous data as age, body mass index….etc. were described as mean and standard deviation.

Chi square Test (χ^2) was used for testing the association or relationship between two or more dichotomous categorical variables. Fisher exact test was used for 2x2 qualitative variables when more than 25% of the cells have expected count less than five; Student t-test was used to compare mean and SD of 2 sets of quantitative normally distributed data, while Mann Whitney test was used when this data is not normally distributed. The ANOVA test used to determine if there were statistically significant differences between two or more groups of an independent variable on a continuous dependent variable; The ROC (Receiver Operating Characteristic) curve was done to detect the cutoff value with highest sensitivity and specificity.

Sensitivity, specificity, positive and negative predictive values and diagnostic accuracy was calculated.

The results were represented in tables and graphs. The level of significance was considered statistically significant if (P value is <0.05).

Results

Mean age of patients at the time of scan was 31.5 years, mean BMI was 29.75 kg/m^2, mean parity was 2.14, mean number of previous cesarean sections was 2.09, mean gestational age at enrollment was 28.97 weeks, gestational age at delivery was 35.44 weeks, mean estimated blood loss was 1.98 L and mean blood units transfused was 2.91 units (Table 1).

Regarding the accuracy of 2D grayscale US parameters for diagnosis of placenta accreta, for number of lacunae more than

4; sensitivity was 70.59%, specificity was 74.24%, positive predictive value (PPV) was 58.54% and negative predictive value (NPV) was 83.5%, absence of hypoechoic retroplacental area, sensitivity was 73.13%, specificity was 69.63%, PPV was 54.44% and NPV was 83.93 and for myometrial thickness less than 1mm; sensitivity was 57.58 %, specificity was 77.94%, PPV was 83.87% and NPV was 48.18% (Table 2).

Regarding the accuracy of 2D color Doppler US parameters for prediction of placenta accreta, for vascular lacunae; sensitivity was 73.35%, specificity was 56.06%, PPV was 46.30% and NPV was 80.46% and for lower uterine segment hypervascularity; sensitivity was 88.24%, specificity was 90.91%, PPV was 83.33% and NPV was 93.75%.

Regarding 3D power Doppler US; VI; sensitivity was 93.9%, specificity was 77.61%, PPV was 67.93% and NPV was 96.3%, for FI; sensitivity was 42.45%, specificity was 59.70%, PPV was 43.15% and NPV was 67.80%, for VFI; sensitivity was 93.94%, specificity was 94.03%, PPV was 88.57% and NPV was 96.92% and for placental volume; sensitivity was 96.88%, specificity was 80.60%, PPV was 70.45% and NPV was 98.18% (Table 2).

Table (1): Demographic Data of Study Participants

Parameter	Mean	Standard deviation	Median	Minimum	Maximum
Age (years)	31.15	3.467	31.0	23	38
BMI ((kg/m^2)	29.75	1.81	31.0	23	34
Parity (n)	2.14	1.07	2.0	1	5
Previous CS (n)	2.09	1.033	2.0	1	5
GA at enrollment (w)	28.97	0.788	29.0	28.0	30.0
GA at delivery (w)	35.44	0.713	36.0	32	37
EBL (L)	1.982	0.749	2.0	1	5
Blood units transfused (n)	2.91	2.208	2.0	0.0	10.0

GA: Gestational age; L: litre; n: number; W: Weeks

Table (2): Validity of 2D and 3D ultrasound variables for diagnosis of placenta accrete spectrum disorders.

Variables	Sensitivity	Specificity	PPV	NPV	Accuracy	AUC
Placental lacunae	70.59	74.24	58.54	83.05	73.0	0.724
Vascular lacunae	73.53	56.06	46.30	80.43	62.0	0.648
Retroplacental hypoechoic zone	73.13	69.63	54.44	83.93	70.79	0.714
Myometrial thickness	57.58	77.94	83.87	48.18	64.53	0.684
Lower uterine segment hypervascularity	88.24	90.91	83.33	93.75	90.00	0.896
VI	93.9	77.61	67.39	96.3	83.0	0.857
FI	42.42	59.70	34.15	67.80	54.0	0.496
VFI	93.94	94.03	88.57	96.92	94.00	0.955
Placental volume	96.88	80.60	70.45	98.18	85.86	0.958

AUC: Area under the curve; PPV: positive predictive value; NPV: negative predictive value; VI: Vascular index; FI: Flow index; VFI: Vascular flow index

Table 3: Grayscale, color Doppler and 3D Power Doppler US markers suggestive of placental accreta spectrum disorders in study participants

Item	Histopathological data		X^2	P value
	Non PASD	PASD		
	No 135 (66.8%)	No 67 (33.2%)		
Placental lacunae			t=	
Mean ±SD	3.02±1.01	7.06±1.56	15.527	<0.001*
Range	2-8	5-10		
Vascular lacunae				
No	76(56.3)	18(26.9)	15.588	<0.001*
Yes	59(43.7)	49(73.1)		
Retroplacental hypoechoic zone				
Absent	41(30.4)	49(73.1)	33.147	P= <0.001*
Present	94(69.6)	18(26.9)		
Myometrial thickness				
<1mm	57(42.2)	53(79.1)	24.559	P= <0.001*
≥ 1mm	78(57.8)	14(20.9)		
Lower uterine segment hypervascularity				
No	123(91.1)	8(11.9)	59.754	FE P= <0.001*
Yes	12(8.9)	59(88.1)		
VI				
Mean ±SD	17.778±4.4	29.515±6.59	10.643	<0.001*
Range	8-26	13-42		
FI				
Mean ±SD	43.55±1.32	43.20±1.81	4.635	0.839
Range	42-45	42-47		
VFI				
Mean ±SD	9.701±1.84	16.424±4.344	10.875	<0.001*
Range	5-15	7-30		
Placental volume (ml)				
Mean ±SD	222.0±25.329	287.90±25.82	12.158	<0.001*
Range	185-295	235-330		

SD: Standard deviation; t: Student t-test; *: Statistically significant at $p \leq 0.05$; VI: Vascular index; FI: Flow index; VFI: Vascular flow index

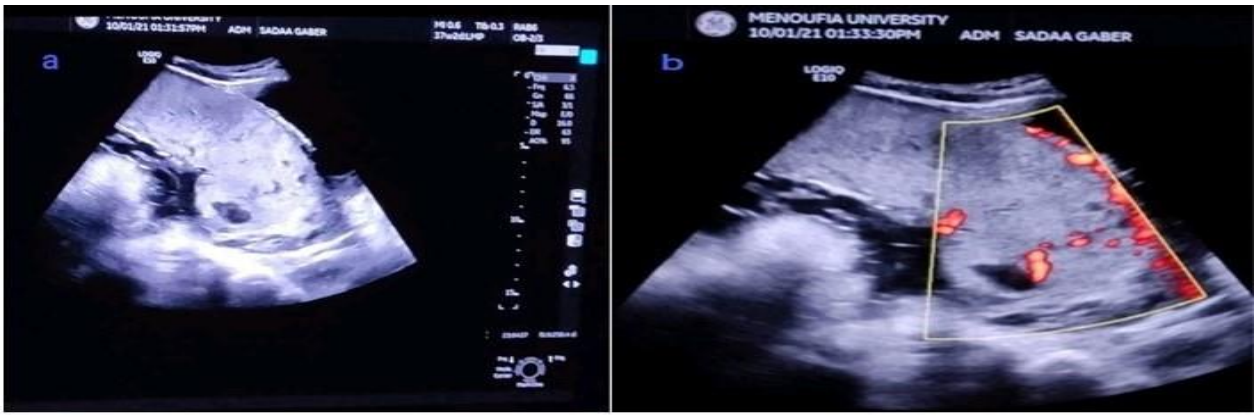

Fig. (1): a) Trans-abdominal 2D grayscale ultrasound at 30 weeks of gestation showing (loss of retroplacental clear space, multiple lacunae with various number, size, shape, thinning and disruption of the uterine serosa b) Trans-abdominal color Doppler ultrasound showing vascularity at placental bladder interference and loss of retroplacental clear disruption of the uterine serosa.

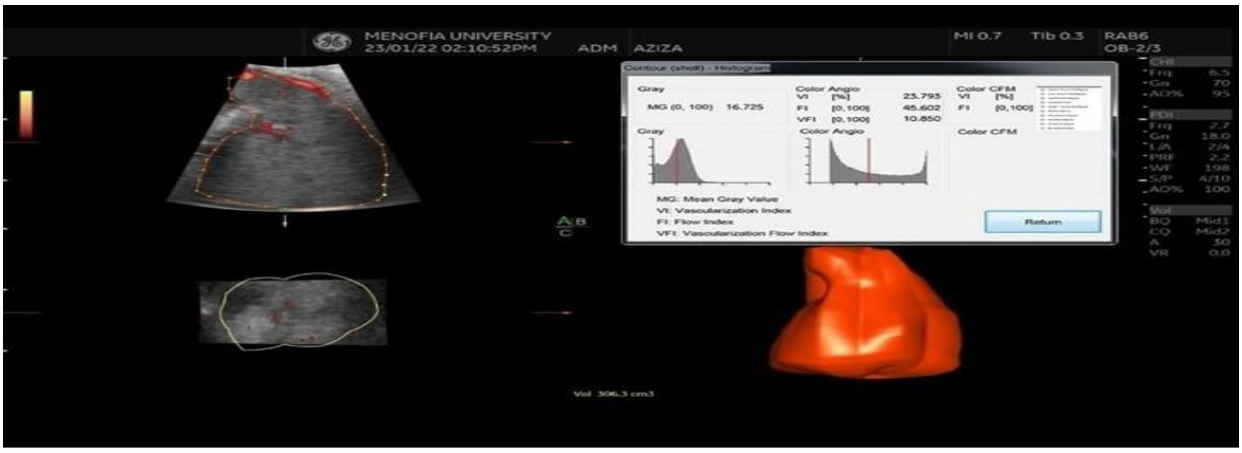

Fig. (2): Trans-abdominal 3D Power Doppler ultrasound at 29 weeks of gestation showing manual tracing, rotation 30 angle and calculation of VI, FI and VFI occur automatically.

Discussion

In this study, grayscale ultrasound parameters were used for prediction of PASD; myometrial thickness less than 1mm had sensitivity and specificity of 57.58% and 77.94% respectively, PPV was 83.87% and NPV was 48.18%. Wonget et al. [11] and Abdel Magied et al. [12] reported sensitivity and specificity of 54.5% and 100% respectively, PPV was 100% and NPV was 70.5%. Shawky et al. [13] reported sensitivity and specificity of 67% and 100% respectively, PPV was 100%, Horowitz et al. [14]

reported a range of sensitivity between 22% and 100%, There was statistically significant difference related to presence of myometrial thickness less than 1mm and risk of PASD based on pathological outcome finding and risk of caesarean hysterectomy (table 3). These results were in agreements with that of Bowman et al. [15], loss of visualization of the myometrium associated with increased risk of PASD.

Absence of the retroplacental hypoechoic area had sensitivity and specificity of 73.13% and 69.63% respectively, PPV was 54.44% and NPV was 83.93% (table 2); Haidar et al. [10]; reported absence of the retroplacental hypoechoic area with sensitivity and specificity of 50% and 63.6% respectively; PPV was 60% and NPV was 53.8%. Tanimura et al. [16]; reported absence of the retroplacental hypoechoic area with sensitivity and specificity of 86.7% and 88% respectively, PPV was 72% and NPV was 95%. Cali et al. [17] reported sensitivity of 90%; Shih et al. [18] reported NPV of disruption of retroplacental hypoechoic area was 85%; Bowman et al. [15] reported sensitivity of 91.9%.

Presence of lower uterine segment hypervascularity detected by 3D power Doppler had sensitivity and specificity of 88.24% and 90.91% respectively, PPV and NPV were 83.33% and 93.75% respectively (table 2). Cali et al. [17] reported that lower uterine segment hypervascularity has NPV of 97%; this is good negative test. This is explained by lower uterine segment hypervascularity which associated with vascularization of the entire placental width; these results were in agreements with that of Shih et al. [18] reported sensitivity and specificity were 97% and 88% respectively, PPV and NPV were 90% and 97% respectively.

Presence of four or more lacunae had sensitivity and specificity of 100% and 93.94% respectively, PPV was 89.47% and NPV was 100% (table 2); Haidar et al. [10] reported sensitivity and specificity were 69.6% and 92.6% respectively, PPV was 88.5% and NPV was 78.1%. Moniem

et al. [19] reported sensitivity of 73.9%; Antonio et al. [20] reported sensitivity of 77.43% and specificity was 95.02%; Cali et al. [17] reported that all cases with placenta percreta had more than six lacunae with turbulent flow inside with sensitivity and specificity were 73% and 86% respectively, PPV was 60% and NPV was 90%, the high negative predictive value of the test made it good negative one. Shih et al. [18] reported a sensitivity rate of 74%. There was a statistically significant difference related to presence of four or more lacunae and risk of PASD based on pathological outcome findings.

When the 3D Doppler indices were compared between pregnancies with PASD requiring caesarean hysterectomy and those without; the mean values of VI, VFI and Placental volume (PV) were significantly higher in the confirmed PASD cases. Sensitivity, specificity and accuracy of VI index were 93.9%, 77.61% and 83.0% respectively; sensitivity, specificity and accuracy of VFI index were 93.94%, 94.03% and 85.86% respectively and FI index had low sensitivity, specificity and accuracy as they were 42.42%, 59.70% and 94.00% respectively (table 2). These results were in agreements with that of Hiadar et al. [10] reported the following; the mean values of VI and VFI were significantly higher in the confirmed PASD, FI values were not statistically significant. In this study VI, VFI and placental volume were significantly higher in the confirmed PASD; FI values were not statistically significant (table 3). Hiadar et al. [10] and this study both concluded that VI accurately predicted PASD in participants with placenta previa. In addition, 3D Power Doppler vascular and VFI were more predictive of PASD compared to grayscale and color Doppler ultrasound.

In this study; 3D power Doppler indices in PASD participants were as the following; mean placental volume was 287.909 ±25.82 ml, mean VI was 29.515 ±6.59, mean FI was 47.91±3.68 and mean VFI was 16.424 ±4.344. These results were in agreements with that of Hiadar et al. [10]

cases of PASD; mean VI was 32.8 ±7.4, mean FI was 42.7±6.7, mean VFI was 14.2±3.8 and mean placental volume was 267.1±10.8 ml (table 3).

In Hussein et al. [21] which also agreed to the use of 3D power Doppler with both grayscale and color Doppler US as complementary techniques; which could improve the antenatal diagnosis or exclusion of PASD, but ended with the same subjective findings that could easily misinterpreted by sonographers.

Strengths and limitations: Strengths in this study were using considerable sample size and the examination was done by single examiner for grayscale, color Doppler US and 3D power Doppler US strengthen this study. Difference in results is related to the modern ultrasound machines allow visualization of the residual myometrium at a greater resolution, so the prevalence of loss of retroplacental hypoechoic area is not as high in occurrence as reported previously. Color Doppler volume studies are currently available in the LOGIQ E10, GE machines and marked decline in bladder and ureteric injuries rate is due to a change in bladder dissection technique and time of dissection; limitations were; study did not assess MRI ability to predict PASD in comparison to 3D Doppler indices, MRI is more expensive and less readily available and VOCAL software offline analysis of placental images of maximum placental thickness using 3D view and such technology is not available to all maternity centers.

Conclusions

Accurate prenatal diagnosis of PASD is a must to reduce maternal and fetal morbidity and mortality. Accurate prenatal diagnosis of PASD allows us to choose the appropriate site and time of delivery, counseling, informed consent, preoperative preparation and post-operative care. MDT is mandatory in PASD pregnant women. Using 3D power Doppler US indices increase efficacy of diagnosis.

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Author's contributions

All authors shared equally in this work. ALL authors read and approved the final manuscript.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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