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The accuracy of 3D-TUI and 3D power Doppler using Alalfy simple criteria in the diagnosis of placenta accreta spectrum

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Background: The aim of our study was to evaluate the accuracy of Three Dimensional Tomographic Ultrasound Imaging (3D-TUI) and 3D power Doppler using Alalfy simple criteria in the diagnosis of placenta previa and PAS (Placenta accrete spectrum) with differentiation of placenta previa (non-adherent placenta) from PAS disorders and determination of its subtypes (Accreta, increta, and percreta). *Methods*: A prospective observational study that included 90 pregnant women was made at Algezeera Hospital, Egypt. A systematic combined approach using Alalfy simple criteria; with applying the ultrasound criteria suggestive of PAS in the 3D-TUI, and 3D power Doppler ultrasound volume was performed to scan the placenta previa and to assess if it is non-adherent or PAS and to determine its subtype (accreta, increta or percreta). *Results*: The study shows a high agreement between the 3D-TUI with 3D power Doppler US using Alalfy simple criteria and the operative findings in the diagnosis and differentiation of placenta previa (non-adherent) from PAS (adherent) and its subtypes. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of the 3D-TUI cuts in diagnosing adherent from non-adherent were 100%, 100%, 100%, 100% and 100%, respectively. 3D TUI-cuts has a diagnostic accuracy of 98.8 percent when compared to operative findings in accurately determining the exact subtype of placenta accreta spectrum. *Conclusion*: The systematic combined approach using Alalfy Simple Criteria for assessment of placenta previa and PAS that entails applying the ultrasound criteria suggestive of PAS in the 3D-TUI—3D power Doppler volume has a high degree of accuracy in the diagnosis of PAS from non-adherent placenta and in accurately diagnosing the subtype of PAS (accreta, increta or percreta). 3D-TUI-cuts facilitates the evaluation of the myometrial thickness and the depth of placental invasion with much better differentiation between different subtypes of PAS with better identification of focal from diffuse invasion with the ability of 3D power Doppler to delineate the vessels invading a part of the myometrium or the whole myometrium, and bridging vessels and high vascularity.

Keywords

Placenta accreta spectrum; TUI; Ultrasound; Placenta; PAS

1. Introduction

Placenta accreta spectrum (PAS) disorders, also known as morbidly adherent placenta (MAP) which involves abnormal adherence of the placenta to the site of implantation. They are classified into three subtypes according to the depth of invasion of the trophoblasts through the myometrium and the uterine serosa into placenta accreta, increta and percreta [1, 2]. Placenta accreta is the mild form in which the chorionic villi embedded directly into the myometrium in the absence of the decidua, placenta increta is diagnosed when the myometrium is invaded by the chorionic villi and Placenta percreta; the most aggressive type in which the chorionic villi penetrate through the entire myometrium or even beyond [3]. These placental abnormalities are commonly associated with an increased risk of maternal morbidity and mortality, mainly due to blood loss, local organ damage, cesarean hysterectomy (33–50%) and serious postoperative complications [4].

The reported incidence of (PAS) varies between 1/1000 and 1/2500 deliveries. The rising rates of caesarean deliveries in the last 50 years increased the incidence of PAS 10 folds than before. Further risk factors include; Placenta previa, other previous uterine surgeries, multiparty, advanced maternal age, Asherman syndrome, and the presence of submucous myoma [5].

Accurate antenatal diagnosis of (PAS) allows proper planning for delivery at a tertiary care unit and a multidisciplinary approach in management [6]. Conventional 2D ultrasound examination with the use of colour and power Doppler can

Table 1. Baseline characteristics data of the women in the study.

	Count	Minimum	Maximum	Mean	Standard deviation
age	90	18.00	41.00	31.98	4.99
BMI	90	25.00	39.00	30.70	3.35
hysterotomies	90	0.00	1.00	0.07	0.25
gestational.age	90	30.00	38.00	35.40	1.64
cesarean.section	90	0.00	4.00	2.34	0.88

Table 2. Correlation between different US criteria of PAS and the operative findings.

		operative.findings							
		Accreta		Increta		Percreta		Non adhehrent	
		Count	%	Count	%	Count	%	Count	%
obliterated.sonolucent.area	yes	16	100.0%	22	91.7%	14	100.0%	2	5.6%
placental.lacunae	yes	16	100.0%	22	91.7%	14	100.0%	0	0.0%
myometrial.thinning	yes	16	100.0%	22	91.7%	14	100.0%	2	5.6%
placental.vascularity	increased	6	37.5%	20	83.3%	12	85.7%	4	11.1%

assess placental morphology, blood flow, and placental vascular trees. Advanced ultrasound technology also is considered a valuable tool in the assessment of normal and abnormal placental changes. Three-Dimensional ultrasonography (3D US) gives more detailed information on the surface anatomy of the placenta. Recent advances, such as 3D power Doppler with the virtual organ computer-aided analysis (VOCAL) and histogram analysis can measure placental volume, assess uteroplacental perfusion and fetoplacental perfusion [7].

Three Dimensional Tomographic Ultrasound Imaging (3D-TUI) is useful for the detection of placental growth into the surrounding structures, e.g., the bladder [8]. This technique increases the contrast between tissues, helps in the assessment of myometrial thickness and early detection of the invasive placenta [9].

The aim of our study was to evaluate the accuracy of Three Dimensional Tomographic Ultrasound Imaging (3D-TUI) and 3D power Doppler in the diagnosis of placenta previa and PAS (Placenta accrete spectrum) with differentiation of placenta previa (non-adherent placenta) from PAS disorders and determination of its subtypes (Accreta, increta, and percreta).

2. Materials and methods

2.1 Patient population

This prospective observational study included 90 pregnant women who were selected from the outpatient and inpatient obstetric department in collaboration with the radiology department at Algezeera Hospital, Egypt in the period from March 2018 till June 2019. The study was approved by the local institutional review board (approval number 0019). History and data collection for the patients were done after obtaining their written consent.

We included in the present study 90 pregnant women who full filled the inclusion criteria and are scheduled for an elective cesarean section which are pregnant women with history of one or more previous cesarean section or previous hysterotomy and with a routine obstetric US showing a placenta previa with the lower placental edge reaches the level of internal os or covering the cervix who were referred from the obstetric clinic to be subjected to a detailed obstetric US for meticulous assessment of the placenta to determine if it is a placenta previa or PAS and with a gestational age range from 30–40 weeks.

A systematic combined approach using Alalfy simple criteria with applying the ultrasound criteria suggestive of PAS in the 3D-TUI , and 3D power Doppler ultrasound volume was performed to scan the placenta previa and to assess if it is non-adherent or PAS and to determine its subtype (accreta, increta or percreta).

Women with any medical disorders such as diabetes mellitus & hypertension and pregnancy-induced hypertension patients or morbidly obese patients with (BMI body mass index >40) were excluded from the study, also, cases who were diagnosed to have placenta previa or suspected to have PAS presenting to the emergency department were excluded from the study due to unavailability of machines and the same observer (fetal medicine specialist) and unsuitability for the study requirements, moreover fetal factors as multifetal pregnancy, Intrauterine growth retardation, IUFD (intrauterine fetal death), premature rupture of membranes, and associated fetal anomalies were excluded from the study.

All cases were subjected to a full history taking; personal history, obstetric history (including the number of C.S, abortion, and placenta previa in a previous pregnancy), and present history (complaint, gestational age & history of antepartum hemorrhage).

2.2 Ultrasound technique

Ultrasound examination was made by Voluson E8 medical systems (Ultrasound General Electric Company, Zipf, Austria) and Voluson E6 medical systems (Ultrasound General Electric Company, Zipf, Austria) in Obstetrics and Gy-

Table 3. Agreement between 3D TUI cuts and operative findings, Number(N) and percent (%).

		operative.findings									
		Accreta		Increta		Percreta		Non adhehrent		Total	
		Count	%	Count	%	Count	%	Count	%	Count	%
TUI.cuts	Accreta	16	100.0%	1	4.2%	0	0.0%	0	0.0%	17	18.9%
	Increta	0	0.0%	23	95.8%	0	0.0%	0	0.0%	23	25.6%
	Percreta	0	0.0%	0	0.0%	14	100.0%	0	0.0%	14	15.6%
	Non adhehrent	0	0.0%	0	0.0%	0	0.0%	36	100.0%	36	40.0%
	Total	16	100.0%	24	100.0%	14	100.0%	36	100.0%	90	100.0%

Table 4. The diagnostic performance of ultrasound criteria using different US modalities each one alone in comparison to all these criteria in 3D-TUI cuts and approaches in detecting either placenta is adherent or non adherent.

	Sensitivity	Specificity	PPV	NPV	Accuracy
Obliterated sonolucent area	96.3%	94.4%	96.3%	94.4%	95.6%
Placental lacunae	96.3%	100.0%	100.0%	94.7%	97.8%
Myometrial thinning	96.3%	94.4%	96.3%	94.4%	95.6%
TUI cuts	100.0%	100.0%	100.0%	100.0%	100.0%

necology department. Routine fetal viability checking was done. Patients were placed in the supine position and abdominal ultrasound examination was performed with the bladder partially filled, which allowed optimal visualization of the uterine serosa and the bladder wall. This was followed by transvaginal US a systematic combined approach using Alalfy simple criteria with applying the ultrasound criteria suggestive of PAS in the 3D-TUI, and 3D power Doppler ultrasound volume was performed to assess placenta previa and to diagnose if it is PAS or non-adherent and to determine its subtype (accreta, increta or percreta).

The whole placenta was scanned in a systematic fashion through performing 3D US volume then applying 3D-TUI and then adding power doppler to 3D (3D power Doppler) ultrasound on the placenta. We used the following ultrasonographic findings suggestive of PAS; obliteration of clear space between the placenta and uterus, decreased myometrial thickness less than 1 mm in the retroplacental area, placental lacunae (irregular vascular spaces), increased placental vascularity, uterine serosa-bladder interface interruption, and invasion of the bladder wall, vessels invading part of the myometrium or the whole myometrium, bridging vessels and we applied these parameters in placental assessment by 3D TUI and in 3D power Doppler; and this is called Alalfy simple criteria for diagnosis of PAS [2, 10, 11]. The diagnosis was made by applying the previously mentioned ultrasound criteria suggestive of PAS in the prenatal 3D softwares; 3D-TUI, and 3D power Doppler ultrasound volume to differentiate placenta previa from PAS and to determine its subtype (accreta, increta or percreta) and then it was correlated with the operative finding to confirm the prenatal diagnosis of the placenta.

During the 3D-TUI technique, the 3D volume of the transducer was mechanically and systematically moved over the defined region of interest (ROI) to obtain the volume data in three planes; sagittal, coronal, and axial.

The collected volume data were analyzed and stored on the machine's hard drive. 3D-TUI allowed a simultaneous display of multiple parallel cuts per volume preselected parallel cuts (slices) from a volume. Findings of the 3D-TUI suggestive of PAS were similar to the 2D grey scale but 3D-TUI represented the sequential sections of the scanned ROI.

The 3D power Doppler was used to analyze the vasculature of the lower uterine segment and placenta. Two views of the 3D power Doppler were generally analyzed; lateral view to observe the intra-placental vasculature and basal view to observe the serosa-bladder interface.

2.3 Image analysis

At least one of the following findings was suggestive of PAS by the 3D power Doppler: Disruption of the retroplacental sonolucent zone with a vascular gap in sub placental vessels, Abnormal placental lacunae, Numerous vessels invading the uterine serosa-bladder interface, Crowded vessels over the peripheral sub placental zone [12].

In the present study, we used the following US parameters; Obliteration of clear space between the placenta and uterus, decreased myometrial thickness less than 1 mm in the retroplacental area, placental lacunae (irregular vascular spaces), placental vascularity, uterine serosa-bladder interface interruption, and invasion of the bladder wall, numerous vessels invading the uterine serosa-bladder interface, Crowded vessels over the peripheral sub placental zone and we applied these parameters in placental assessment by 3D TUI and 3D power Doppler in the so, called Alalfy simple criteria for the diagnosis of PAS and were correlated it with the operative finding to confirm the prenatal diagnosis of the placenta.

2.4 Standard of reference

Both operative and pathological findings were used as the standard reference of PAS diagnosis. Operative and/or pathological criteria including; adherence of the placenta to or invading through the myometrium.

Table 5. Maternal complications of placenta accrete spectrum (PAS) and non-adherent placenta.

	operative.findings									
	Accreta		Increta		Percreta		Non adhehrent		Total	
	Count	%	Count	%	Count	%	Count	%	Count	%
antepartum.hge	4	25.0%	14	58.3%	8	57.1%	18	50.0%	44	48.9%
preterm.delivery	12	75.0%	17	70.8%	9	64.3%	17	47.2%	55	61.1%
hysterectomy	2	12.5%	24	100.0%	14	100.0%	0	0.0%	40	44.4%
urinary.bladder.injury	0	0.0%	4	16.7%	14	100.0%	0	0.0%	18	20.0%

Table 6. Agreement between 3D TUI focal or diffuse PAS and operative focal PAS findings.

		Operative focal							
		Focal PAS		Diffuse PAS		Non adherent		Total	
		Count	%	Count	%	Count	%	Count	%
TUI focal	Focal PAS	28	100.0%	1	3.8%	0	0%	26	28.9%
	Diffuse PAS	0	0.0%	25	96.2%	0	0.0%	28	31.1%
	Non adherent	0	0.0%	0	0.0%	36	100%	36	40.0%
	Total	28	100.0%	26	100.0%	36	100.0%	90	100.0%

All patients findings in the operative, postoperative, pathological findings and occurrence of peripartum complications in both mother, fetus and neonate were recorded and statistical analysis for them was made as maternal mortality, blood transfusion, injury of the urinary bladder, ureteric injury and Cesarean hysterectomy, although they were not the primary objective of the study.

2.5 Statistical methods

Data were statistically described in terms of mean ± standard deviation (±SD), and range, or frequencies (number of cases) and percentages when appropriate. Correlation between various variables was done using Spearman rank correlation equation. Accuracy was represented using the terms sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy. Receiver operator characteristic (ROC) analysis was used to determine the optimum cut-off value for the studied diagnostic markers. p values less than 0.05 was considered statistically significant. All statistical calculations were done using the computer program IBM SPSS (Statistical Package for the Social Science; IBM Corp, Armonk, NY, USA) release 22 for Microsoft Windows.

3. Results

This prospective observational study included 90 pregnant women who full filled the inclusion criteria and are scheduled for elective caesarean section. Table 1 shows the baseline characteristics of the women included in the study regarding their age, gestational age at US scan, BMI, a history of repeated cesarean section.

Placenta previa was found in all cases; 76 complete Previa and 14 cases with marginal Previa [13]. The non-adherent placenta was found in 36 cases and a suspected diagnosis of placenta accreta spectrum (PAS) was in 54 cases. All cases with PAS were complete Previa except 2 cases of percreta and 4 cases of increta were marginal Previa. Cases with non-adherent placenta included 28 cases with complete Previa and 8 with marginal Previa.

Table 2, shows the presence of different ultrasound finding suggestive of PAS in the 3D TUI cuts and in 3D power Doppler; (obliterated sonolucent area, placental lacunae, myometrial thinning and increased placental vascularity) in pregnant women included in the study with assessment of each ultrasound finding in all cases to help in the diagnosis of either Previa, accrete, increta or percreta. We found that the maximum sensitivity was found in obliterated sonolucent area, placental lacunae, and myometrial thinning (Table 2).

Interruption of urinary bladder line and bridging blood vessels were found in all percreta cases. While increta cases showed interruption of bladder line in 4 cases and bridging vessels in 2 cases. Regarding cases of percreta; bridging vessels detected by 3DPD (3 Dimensional power Doppler) and interruption of bladder uterine interface showed high diagnostic accuracy and they were highly significant in the diagnosis of percreta cases (all case of percreta were diagnosed prenatally).

Ultrasound examination using 3D-TUI cuts revealed that the number of placenta accreta spectrum (PAS) cases were 16/90, 23/90 and 14/90 accrete, increta (As seen in Figs. 1,2,3) and percreta respectively. The number of cases with non-adherent placenta was 36/90 cases. 3D-TUI technique could detect whether focal or diffuse placenta accreta spectrum due to the multiple thin cuts of the examined part. 3D-TUI cuts accurately diagnosed all cases of accreta, percreta types and non adherent placenta. Regarding the placenta increta; correctly diagnosed 23 cases and one case only misdiagnosed as accreta but when adding the 3D power Doppler to the 3D-TUI with applying Alalfy simple criteria it properly diagnosed all cases of increta.

The results of operative findings were compared to find-

Table 7A. Shows 3D TUI cuts in relation to operative findings as regard adherent and non - adherent placenta.

		Operative findings					
		Adherent			Non adherent		
		Count	Column N %	Row N %	Count	Column N %	Row N %
3DTUI. cuts	adherent	54	100.0%	100.0%	0	0.0%	0.0%
	non adherent	0	0.0%	0.0%	36	100.0%	100.0%

Table 7B. Shows the diagnostic accuracy of 3D TUI cuts in differentiation of PAS from non - adherent placenta.

	Sensitivity	Specificity	PPV	NPV	Accuracy
TUI cuts	100.00%	100.00%	100.00%	100.00%	100.00%

ings of 3D-TUI cuts. Assessment of diagnostic performance of 3D-TUI cuts (Table 3).

The overall agreement between 3D-TUI cuts and operative findings in accurately diagnosing PAS subtypes (accrete, increta and percreta) was 98.8% and the overall agreement between the combined approach 3D TUI cuts and operative findings in accurately diagnosing PAS subtypes (accrete, increta and percreta) was one hundred percent. The sensitivity, specificity, PPV (positive predictive value), NPV (negative predictive value), and accuracy of the 3D-TUI cuts in detecting morbidly adherent placenta from non-adherent placenta were 100%, 100%, 100%, 100% and 100%, respectively. The diagnostic performance of different ultrasound criteria detected in our study groups were illustrated in (Table 4).

Urinary bladder injury was detected in 18 cases involving; 4 increta and all percreta cases, no maternal mortality or ureteric injuries had occurred. 55 pregnant women underwent preterm delivery (Table 5).

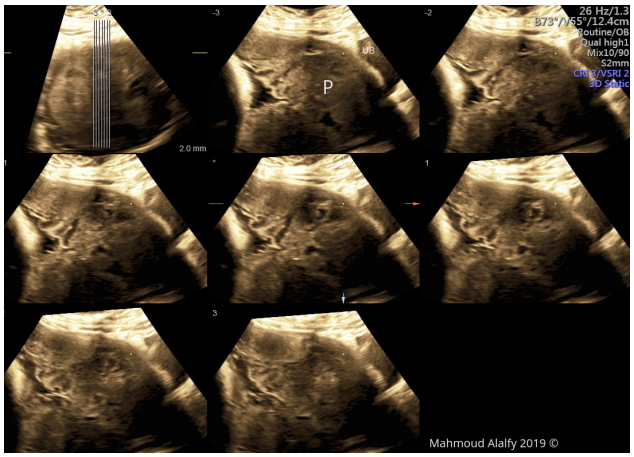

Fig. 1. Shows 3D TUI in a case of placenta increta. TUI cuts shows a placenta invading the myometrium with delineation of the thin myometrial thickness over a long distance in the area of the placental implantation site suggestive of increta (large longitudinal arrow) and obliterated sonolucent area (small transverse arrow). UB, urinary bladder; P, Placenta.

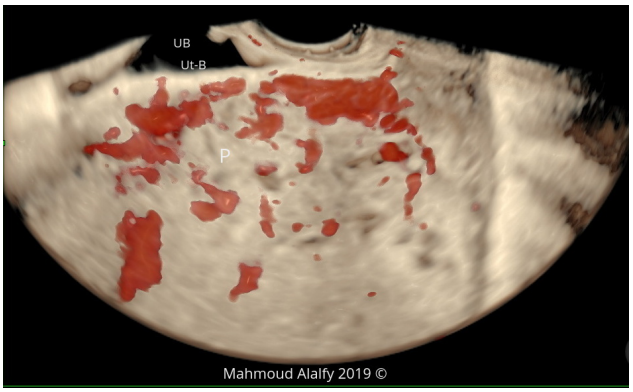

Fig. 2. 3D Power Doppler. Demonstrating the placenta and the placental vessels invading the myometrial wall (large longitudinal arrow) and shows the placental hyper vascularity (transverse arrow). UB, urinary bladder; Ut-B, uterine bladder interface; P, Placenta.

4. Discussion

Ultrasonography is considered an effective method for evaluating the placental invasion of the myometrium before delivery. If the thickness at the site of placental invasion was only 1 mm, severe placenta increta/percreta invading the myometrium to the serosal uterine layer would be considered. This was best visible by trans abdominal ultrasound with Three Dimensional Tomographic ultrasound imaging (3D-TUI), which is a new application of 3D ultrasound that displays thin slices from an acquired volume. Many authors approved that 3D multislice view Doppler showed a higher diagnostic accuracy of placenta accreta spectrum (PAS) disorders compared with the 3D power Doppler [14].

Placenta accreta spectrum (PAS) is considered a significant obstetric challenge. Placenta accreta is often used as a general term but it is further classified according to the degree of invasion of chorionic villi into maternal myometrium [15]. Placenta accreta spectrum(PAS) are classified into accreta, increta and percreta based on the depth of myometrial invasion: superficial, deep, and extension through the uterine serosa, respectively. The more the degree of myometrial invasion, the higher the risks for maternal complications [16]. PAS accounts for nearly 40–60% of emergency hysterectomy cases [17, 18].

Table 8. Agreement between (adding 3D power Doppler to 3D TUI cuts) in comparison to operative findings.

		operative.findings									
		Accreta		Increta		Percreta		Non adhehrent		Total	
		Count	%	Count	%	Count	%	Count	%	Count	%
TUI+PD	Accreta	16	100.0%	0	0.0%	0	0.0%	0	0.0%	16	17.8%
	Increta	0	0.0%	24	100.0%	0	0.0%	0	0.0%	24	26.7%
	Percreta	0	0.0%	0	0.0%	14	100.0%	0	0.0%	14	15.6%
	Non adhehrent	0	0.0%	0	0.0%	0	0.0%	36	100.0%	36	40.0%
	Total	16	100.0%	24	100.0%	14	100.0%	36	100.0%	90	100.0%

Fig. 3. Demonstrates a postoperative specimen of post hysterectomy showing placenta increta.

In the present study, we found that placenta accreta spectrum cases were 54 out of 90 cases; 16 cases were accreta, 24 cases increta, and 14 percreta.

Silver *et al.* [19], they reported an increased risk of placenta accreta in women with a known placenta previa and with an increasing number of cesarean deliveries. The risk of placenta accreta was 3%, 11%, 40%, 61%, and 67% for first, second, third, fourth, and fifth or more cesarean deliveries, respectively.

In our study all cases were placenta previa, the incidence of placenta accreta spectrum (PAS) was 60% of cases. All cases gave a history of previous cesarean delivery except one case with history of hysterotomy.

Placenta accrete spectrum is more common in cases of an anteriorly located placenta. The anteriorly located placenta is commonly associated with an increased risk of early bleeding and preterm delivery [20]. In our study; we found that all cases with invasive placentation had placenta previa anterior with increased incidence of preterm delivery.

Tikkanen *et al.* [21] found that the risk factors of PAS included cesarean section and placenta previa. In our study, we found that 98% of the examined pregnant women gave a history of previous cesarean sections.

Maternal mortality has been reported in up to 7% of cases of placenta accreta [22]. In the current study, there were no maternal deaths. This may be due to management by a multidisciplinary team in a tertiary center with proper patient diagnosis preoperatively, adequacy and availability of blood and blood products for transfusion, experienced surgical team, and availability of resources which improved maternal and fetal outcomes.

Bowman *et al.* [23] stated that ultrasound diagnosis of placenta accreta was associated with the presence of placental lacunae, obliterated retro placental myometrial space, or abnormalities in color Doppler. Obliterated retroplacental space is considered a sign of placenta accreta with a reported detection rate of 93%. False-positive cases may occur in 20–50% of cases with the normal placenta [3, 24]. While Comstock *et al.* [25] found that the absence of retroplacental space is not a diagnostic sign for PAS because retroplacental space may be absent in cases with the normal placenta.

This is in agreement with the present study, we used the following US parameters; Obliteration of clear space between the placenta and uterus, decreased myometrial thickness less than 1 mm in the retroplacental area, placental lacunae (irregular vascular spaces), placental vascularity, uterine serosa-bladder interface interruption, and invasion of the bladder wall, numerous vessels invading the uterine serosa-bladder interface, Crowded vessels over the peripheral sub placental zone and we applied these parameters in placental assessment by 3D TUI and 3D power Doppler in the so, called Alalfy simple criteria for the diagnosis of PAS and were correlated it with the operative finding to confirm the prenatal diagnosis

of the placenta, it revealed that it can increase the diagnostic accuracy of PAS through the advantage of determining the depth of placental invasion, vascularity, and which type of PAS (either accreta, increta and percreta) as shown in Table 3.

Wong *et al.* [26] concluded that the loss of retroplacental space and the presence of abnormal vessels crossing this interface was the most specific criteria to diagnose PAS using 2D gray-scale ultrasound examination.

In our study, we found that obliterated retroplacental space was detected in 96.3% of cases with PAS, with an accuracy of 95.6%. Loss of retroplacental space showed significant relation with the diagnosis of PAS. Also, the presence of bridging vessels and interruption of bladder line when 3D TUI with power Doppler was added, it have a high accuracy in diagnosing placenta percreta with a sensitivity of 100% and specificity 100%.

So-Yeon *et al.* [27] reported an increased incidence of the need for blood transfusion and cesarean hysterectomy in cases with increasing grade of placental lacunae.

This is in agreement with the current study as blood transfusion increased in patients who had placental lacunae. CS (caesarean section) hysterectomy also increased in patients who had placental lacunae and bladder injuries with the presence of lacunae.

A meta-analysis by D'Antonio *et al.* [10] compared twenty-three studies involving over 3700 patients. They found that the sensitivity of individual studies for detection of placenta accreta spectrum ranged from 61% to 100%. They reported that abnormal vasculature on color Doppler examination and abnormalities on the uterine-bladder interface had the greatest sensitivity and specificity while the presence of placental lacunae and loss of retroplacental space showed the lowest sensitivity and specificity in predicting PAS.

Whereas in the present study, we found that the maximum sensitivity was found in obliterated sonolucent area, placental lacunae, and myometrial thinning.

Chou *et al.* [28] found that color Doppler had 82.4% sensitivity, 96.8% specificity, 87.5%, and 95.3% positive and negative predictive values.

Shih *et al.* [29] showed that that 3D power Doppler increased the detection rate for placenta accreta to 76% in comparison to grayscale (51%) and color Doppler (47%) ultrasonography. 3D power Doppler can be added to grayscale ultrasound for antenatal diagnosis of placenta accreta cases.

In our study, we showed that using all parameters in a volume of 3D TUI with power Doppler increased sensitivity for detection of PAS to 100% in comparison to using one parameter only; myometrial thinning alone (96.3%).

Moreover, in the present study, we found that crowded and bridging vessels over the peripheral retro-placental zone showed high sensitivity and specificity in detection of difficult placental separation and considerable intraoperative blood loss.

Henrich and Stupin [9] reported that transabdominal and transvaginal 2D scans have difficulties due to limited penetration. However, they reported that the 3D-TUI technique has much better image quality and allows a proper assessment of myometrial thickness and depth of placental invasion. This occurs due to much better differentiation between various tissues compared to the 2D ultrasound scan.

This is in agreement with the present study, we found that 3D-TUI technique & 3D Power Doppler studies with applying the ultrasonographic criteria in the 3D volume using Alalfy simple criteria facilitated a precise evaluation of the placental surface features and placental vascular trees and a good delineation of placental invasion and thickness of myometrium.

Three dimensional TUI technique was used for the evaluation of placental invasion to the myometrium. 3D-TUI provided a higher resolution of the whole uterine wall. It delineated myometrial thickness over a long distance of placental implantation site by displaying multiple thin cuts of the area of interest [30].

This is in agreement with the results of the current study, we reported that 3D-TUI increased the accuracy of diagnosis of PAS. The specificity and sensitivity of 3D-TUI were 100% and 100% respectively, that denotes its high capability in the diagnosis of PAS from the non-adherent placenta.

In the present study, 3D-TUI technique increased accuracy of diagnosis of focal PAS as it showed the whole myometrial thickness by displaying multiple thin cuts of the examined area leading to pick up easily focal area of invasive disorders. So 3D-TUI proved its value in the prediction of invasive placental disorders with the proper definition of its subtype and its focal and diffuse pattern as shown in Table 6 and Table 7B.

The results of operative findings were compared to findings of 3D-TUI cuts. Assessment of diagnostic performance of 3D-TUI cuts in classification of PAS and non-adherent placenta were shown in Table 3; which denotes a diagnostic accuracy of 98.8 percent when compared to operative findings in accurately determining the exact subtype of placenta accrete spectrum (accurately diagnosing either accreta, increta or percreta). Moreover, the diagnostic performance of 3D-TUI cuts and 3D power Doppler in classification of PAS and non-adherent placenta in comparison to operative finding is shown in Table 8.

The limitation of this study could be that it only involved the scheduled cases for planned CS with placenta previa and PAS and did not involve women coming for emergency CS with placenta previa or PAS so, the number was limited. Future studies are needed with a larger sample size and involvement of women in the emergency room with a diagnosis of placenta previa or PAS with the availability of a fetal medicine specialist. Also the sensitivity and specificity of 3D-TUI in our results showed one hundred percent accuracy in differentiating adherent from non adherent placenta but 3D TUI cuts alone has 98.8 percent agreement with the operative finding regarding the exact subtype of PAS while applying the US

feasures suggestive of PAS with combining 3D-TUI cuts to 3D Power Doppler in the systematic combined approach ;the so called (Alalfy simple criteria) increased the sensitivity and specificity of diagnosing subtypes to one hundred percent, this could be attributed to the ability of 3D power Doppler to delineate the placental vessels invading part of the myometrium or the whole myometrial thickness or invading the bladder (bridging vessels) to accurately refine the diagnosis of PAS into accreta, increta or percreta (Tables 3,8). The specificity and sensitivity of 100% is likely due to the study being small if more patients were studied the sensitivity and specificity could decrease.

5. Conclusions

The systematic combined approach using Alalfy Simple Criteria for assessment of placenta previa and PAS with applying 3D TUI and 3D power Doppler has a high degree of accuracy in the diagnosis of PAS from non-adherent placenta (one hundred percent accuracy), facilitates the evaluation of the myometrial thickness and the depth of placental invasion with much better differentiation between different subtypes of PAS. when 3D TUI was used alone, it gave a diagnostic accuracy of 98.8 percent when compared to operative findings in accurately determining the exact subtype of placenta accrete spectrum (accurately diagnosing either accreta, increta or percreta) with better identification of focal from diffuse invasion.

So, it is better to do 3D US with TUI in a combination with 3D Power Doppler to it with applying Alalfy Simple Criteria to increase the diagnostic accuracy of PAS with accurate identification of its subtype (either accreta, increta or percreta) as it increased the sensitivity and specificity to one hundred percent in the results of our study when using Alalfy Simple Criteria for assessment of placenta previa and PAS that entails applying the ultrasound criteria suggestive of PAS in the 3D –TUI – 3D power Doppler volume that includes; obliteration of clear space between the placenta and uterus, decreased myometrial thickness less than 1 mm in the retroplacental area, placental lacunae (irregular vascular spaces), increased placental vascularity, uterine serosa-bladder interface interruption, and invasion of the bladder wall, numerous vessels invading the uterine serosa-bladder interface, Crowded vessels over the peripheral sub placental zone with the ability of 3D power Doppler to delineate the vessels invading a part of the myometrium or the whole myometrium, and bridging vessels and high vascularity.

Ultrasound reevaluation of placental invasion is better to be done in the third trimester to decrease false-negative cases.

The results obtained from this study and the technique used can be generally applied in the practice before any scheduled operative intervention for any placenta previa or suspected PAS cases by a fetal medicine specialist.

Abbreviations

PAS, placenta accreta spectrum; MAP, morbidly adherent placenta; TUI, tomographic ultrasound imaging; PPV, positive predictive value; NPV, negative predictive value; VOCAL, virtual organ computer aided analysis; PI, pulsitility index; BMI, body mass index; IUFD, intrauterine fetal death; CS, caesarean section; TVS, transvaginal sonography; NICU, neonatal intensive care unit; 3DPD, three-dimensional power Doppler.

Author contributions

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. In addition to the above mentioned regarding the manuscript, also MA made the US for women and made Cesarean section to women. ST, AA and EK made the US for Women. AE, AA, AR, MAS, HH, ON and AI made the Cesarean sections for the women. HK was the urological consultant that shared in the urolological management for the cases and M the anesthesia consultant for the Cesarean sections.

Ethics approval and consent to participate

The study was conducted after taking the approval of the institutional review board (Algezeera hospital ethical committee, approval number 0019). Clinicaltrials.gov identification ID: NCT03416296. An informed consent was obtained from the participants of the study in which the work was undertaken and that it conforms to the provisions of the Declaration of Helsinki.

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Conflict of interest

The authors declare no conflict of interest.

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