Frontiers in Health Informatics
ISSN-Online: 2676-7104
www.healthinformaticsjournal.com
2025; Vol 14: Issue 2
Open Access

Shear Wave Elastography in Assessment of Placental Stiffness of Different Grades of Placental Invasion in Third trimester

Riyadh W. Al Esawi[1], Furqan Sultan Kadhim[2]

[1,2]Faculty of Medicine, University of Kufa, Dept. of Radiology.
E-mail: riyadh.alisawi@uokufa.edu.iq

Cite this paper as: Riyadh W. Al Esawi, Furqan Sultan Kadhim (2025) Shear Wave Elastography in Assessment of Placental Stiffness of Different Grades of Placental Invasion in Third trimester..*Frontiers in Health Informatics*, *Vol.14, No.2*, 2499-2509

ABSTRACT:

Background: Placenta accreta spectrum is abnormal invasion of the uterine myometrium by the placenta. Prenatal diagnosis of placenta adherent spectrum is vital to provide effective management. Aim: To assess the placental stiffness in different grades of myometrial invasion. Methods: A case-control study was carried out in Al-Zahraa Hospital, Al-Najaf Governorate, Iraq. The study was carried out between the 1st of December, 2023, and the 30th of September, 2024. Included two groups, Placental-myometrial invasion group A and control group B, each group including 50 participants. All pregnant ladies were examined by grayscale ultrasonography, Doppler study, and 2D shear wave elastography. Results: The mean age of the placental accreta spectrum group was older than that of the pregnant women with normal placentae, with a significant difference of 33.6±5.8 vs. 30.4±6.9 years. The frequency of placental accreta spectrum increases with the increment in parity and gravity and the number of cesarean sections significantly. The median elasticity value was significantly higher among patients with placental accreta spectrum, with a mean ±SD of 7.8±2.4 vs 3.1±0.2 KPa in the control group. There was a highly significant difference in median elasticity values among the placental adhesion grades as median elasticity value increased progressively from normal placenta to accreta, increta, and percreta cases. There was a strong correlation between ultrasound and operative findings, confirming the reliability of ultrasound in diagnosing placental adhesions. Ultrasound was highly effective for diagnosing placenta accreta and percreta, while it shows moderate sensitivity for placenta increta and high specificity across all grades, with a good diagnostic accuracy ranging from 88% for accreta, 93% for increta, and 100% for percreta. Conclusions: Older age, multiparity, multigravida, and prior CS were highly associated with placenta-myometrial invasion. Placental stiffness is significantly higher in pregnancy with placenta accreta spectrum than

pregnancy with normal placentae. Shear wave elastography can be included with grayscale ultrasound and Doppler study in the assessment of placenta accreta spectrum..

Keywords: Shear wave elastography, placenta accreta spectrum, myometrium invasion, ultrasound..

INTRODUCTION

The placenta is a remarkable organ that undergoes rapid growth and differentiation during a relatively short life span and forms the interface between a mother and her fetus. It is responsible for the exchange of gases and nutrients, immunologic protection, and secretion of various hormones that affect physiological changes during pregnancy, given its importance to fetal growth and development. Placental abnormalities can have profound implications for fetal and maternal morbidity and even mortality. (1)

1.1. Abnormal Placental Attachment

Placenta accreta complicates 5 to 10 percent of pregnancies with placenta previa. Placenta accreta is abnormal placental implantation in which the anchoring chorionic villi attach to the myometrium, rather than being contained by decidua. The normal decidua basalis and fibrinoid layer (Nitabuch's layer) are defective and as a result the placental villi adhere to the myometrial layer and may penetrate through it to reach other structures. There are three levels of invasive placentas. The first is accreta where the placenta adheres to the fetal surface of the myometrium. The second is increta where the placenta invades into the myometrium. The third is placenta percreta where the placenta invades all the way through the myometrium and often into the bladder wall and or into the bladder cavity itself if the placenta is anterior. Abnormal placentation may also occur posteriorly which is not as common and more difficult to diagnose by ultrasound.(2)

.

The term placental attachment disorder is also used to describe morbidly adherent placenta. Attempted removal of such a morbidly adherent placenta at the time of delivery can result in profound, life-threatening hemorrhage; thus, accurate antenatal diagnosis is extremely important for delivery planning.[1] Many clinical risk factors have been identified; the most significant remain placenta previa and history of prior cesarean delivery, such that placenta previa with a history of 1, 2, or 3 prior cesarean deliveries carries an a priority risk for accreta of 11%, 40%, and 61%, respectively.[3] Antenatal diagnosis of placenta previa-accreta allows effective management planning to minimize mortality and morbidity and is useful for modifying patients' risks. The diagnosis is usually made by ultrasonography (US) or magnetic resonance imaging (MRI) techniques.[4] Pelvic ultrasound is regarded as the most commonly used imaging modality for the diagnosis of placenta previa-accreta.[5] Ultrasound is 85% sensitive for the detection of placenta accreta in high-risk women. The normal hypoechoic placental-myometrial interface is obscured and the placenta appears continuous with the myometrium. Color Doppler is also sensitive (82%) and specific (97%) for the diagnosis of placenta previa/accreta when four criteria are used. The criteria are diffuse and focal intraparenchymal placental lacunar flow, hypervascularity of the bladder and uterine serosa, prominent sub placental venous complex and loss of sub placental Doppler vascular signals. Haematuria may also support the diagnosis of placenta percreta. [6]

The placental findings significantly associated with positive diagnosis include presence of irregular placental vascular lacunae, loss of retro placental "clear space," placental bulging into the myometrium, and an irregular bladder wall (Fig 1.1).[2] Color Doppler is useful for showing turbulent flow in vascular lacunae, referred to as "tornado vessels," and vessels extending beyond the myometrium; it has been reported to improve the sensitivity of gray-scale ultrasound alone for diagnosis of morbidly adherent placentation.[7]

Shear wave elastography (SWE) is a novel ultrasonography technique, which is used to obtain elasticity information that represents the constituent of soft tissues. Application of this technique in obstetrics has recently been documented. Studies concerning the placentas of preeclamptic and diabetic patients have been reported.[3] SWE has identical ultrasound safety considerations to Doppler imaging, which is considered safe for use during pregnancy within American Institute for Ultrasound in Medicine (AIUM) limits. Placenta previa-accreta may cause structural abnormalities that may affect placental stiffness. Evaluation of placental elasticity may facilitate the diagnosis of placenta previa and accreta.[4]

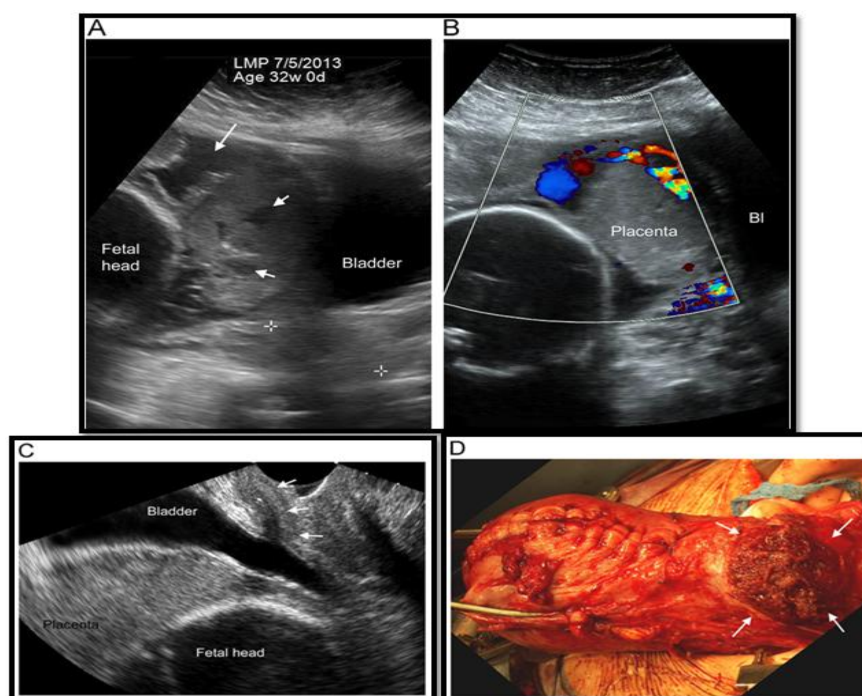


FIG 1.1 Morbidly adherent placenta. (A) TAUS in a patient with 5 prior cesarean deliveries shows abnormal placental echogenicity with multiple large lacunae (arrows). The region of the cervix is indicated by the asterisks. (B) color Doppler in the same case shows swirling blood flow in the largest lacuna seen on gray-scale imaging. (C) TVUS in a different case shows placenta extending to the bladder wall without intervening

myometrium.. The asterisks delineate the urethra. (D) An Intraoperative photograph during cesarean hysterectomy shows placenta percreta (arrows) with placental tissue extending through the old hysterotomy and into the broad ligament.[8]

1.2. Elastography on Dysfunctional Placentas.

A recent prospective study on the causes of stillbirth showed that placental and umbilical cord abnormalities are the main lethal factors for more than 90% of stillbirths, mainly involving placental poor perfusion and bleeding.[9] Maternal diseases such as gestational hypertension, gestational diabetes, and immune system disorders can lead to the failure of trophoblast cell infiltration and spiral artery remodeling, which, in turn, can result in prolonged placental malperfusion, placental cell stress, and failure of placental cell proliferation. Severe ischemic and hemorrhagic injuries can also lead to placental tissue fibrosis. These pathological alterations result in increased placental parenchymal stiffness, decrease the exchange of materials between the placenta and fetus, and impede the exchange of maternal fetal gases and nutrients.[10,11]

Most intrauterine growth restriction (IUGR) cases are caused by placental defects.[12] Thus, placental elasticity values are higher for IUGR fetuses; Placental elasticity values are significantly and positively correlated with the Doppler indices of uterine and umbilical arteries and with adverse clinical outcomes. Therefore, SWE could serve as a new technique for the effective diagnosis and prediction of IUGR, while increased placental stiffness could also serve as a useful predictor for worsened perinatal outcomes. A recent study showed that pregnant women with hard placentas in the second trimester of pregnancy are more likely to experience adverse obstetric outcomes.[13]

2. Patients and Methods

2.1 Study Design and Settings

This study was a case control study carried out in Al-Zahraa hospital- Al Najaf governorate -Iraq. The study carried out between 1st of December 2023, and 30 of September, 2024.

2.2 Study Population

A total of 100 pregnant ladies in their third trimester had been referred to sonographic department of Al-Zahraa hospital, 50 pregnant ladies with normal pregnancy and normal anterior placenta and other 50 pregnant ladies with placenta previa. All of the ladies were examined by single ultrasound equipment. Firstly by B-mode, Doppler study and then by Shear Wave Elastography to assess placental stiffness. All ladies were followed post-delivery whether normal vaginal delivery or cesarean delivery.

2.3 Inclusion Criteria.

Pregnant ladies with normal pregnancy and normal anterior placenta, other pregnant ladies with placental myometrium invasion, both groups are in third trimester.

2.3 Exclusion Criteria

Pregnancies with fetal congenital anomalies.

Pregnancies with retro placental and sub chorionic hemorrhage.

Pregnancies with severe polyhydramnios.

2.4 Ethical Considerations:

An approval was taken from the Scientific committee of the Iraqi board of diagnostic radiology.

An oral informed consent was taken from all pregnant ladies.

2.5 Techniques

2.5.1. Gray-scale US

The ultrasonic examination carried out using GE LOGIC E9 XDClear ultrasound system equipped with a convex probe (C1-6 probe). Examinations were taken with the patient lying in recumbent position with exposed abdomen; warm gel was applied to the abdomen to facilitate imaging, followed by general conventional gray scale 2D B-mode ultrasound imaging.

In the B-mode examination, various fetal biometric measurements were recorded, including biparietal diameter, femur length, fetal weight. The initial diagnosis of placenta accrete was made by US examination. After completing the B-mode imaging, Doppler studies were performed to obtain the resistive index (RI), systolic-to-diastolic ratio (S/D), and pulsatility index(PI). Then all pregnant ladies were examine by SWE.

2.5.2 SWE Examination

Shear-wave elastography was subsequently performed to measure placental stiffness. The placental image was centralized in the field of view. The probe was positioned perpendicular to the skin, gently held to avoid excessive compression. A homogenous area of the placenta was selected for measurement. The measurement box, approximately (1×1 cm) in diameters was positioned within a maximum distance of 10cm from the anterior

Variables	Subgroup	Group Group A No.(%)	 Group B No.(%)	Total	P value
Age (years)		33.6±5.8	30.4±6.9		**0.02***
DM	Yes	11(22%)	6(12%)	17(17%)	0.2
	No	39(78%)	44(88%)	83(83%)	
HTN	Yes	9(18%)	6(12%)	15(15%)	0.4
	No	41(82%)	44(88%)	85(85%)	
Liquor	Normal	34(68%)	41(82%)	75(75%)	0.2
	Mild poly	5(10%)	2(4%)	7(7%)	
	Mild oligo	7(14%)	4(8%)	11(11%)	
	Moderate poly	0(0%)	2(4%)	2(2%)	
	Moderate oligo	3(6%)	1(2%)	4(4%)	
	Severe oligo	1(2%)	0(0%)	1(1%)	

abdominal wall.

Patients were instructed to, empty urinary bladder before the beginning of the exam, breathe slowly and remain still for five seconds, with measurements performed during a period of fetal rest, and avoid uterine contraction during the procedure. The imaging process used an adjustable trapezoid-shaped imaging box, and stiffness measurements were obtained using a round and free region of interest (ROI).After applying a color scale that represented the stiffness within the imaging box (ranging from blue to red), the images were frozen, and stiffness values were recorded in kilopascals (kPa).A total of 10 stiffness measurements were obtained from coded zones, including the fetal surface maternal surface, central part, thickest part, and peripheral parts of the placenta. The results, including the mean stiffness value, were documented in a worksheet. The depth was not exceed 10 cm and penetration was feasible, were included for measurement. The total duration of the examination for each patient was approximately ten to fifteen minutes. Stiffness was defined as the mean of several successful SWE measurements for each pregnant lady.

3.1 Results

A total of 100 pregnant ladies were included, divided into two groups; group (A) diagnosed with PAS and group (B) was control group with normal pregnancies. The mean age± SD of group A was 33.6±5.8 years, which was slightly older than group B 30.4±6.9 years with significant difference p value <0.02. Regarding other parameters like diabetes and hypertensive status of the pregnant ladies, there was no significant difference between study groups. so does the liquor status among the study groups as shown in table (3.1).

Table 3.1: Age, medical history and liquor amount comparisons of the study groups

DM; diabetes mellitus ,HTN; hypertension, poly; polyhydramnios, oligo; oligohydramnios.

Among the study groups, there was a highly statistically significant difference between numbers of both gravity and parity, as the frequency of Placental accreta spectrum increase with the increment in gravity and parity (p-value <0.01, moreover; cesareans-section were highly associated with placental adhesion disorders (group A). There was no statistical difference between number of abortion between both groups. (3-2)

Table 3.2 : Obstetric History of the Study Groups

* The result was significant at P-value <0.05, CS; cesareans-section.

Table 3.3:: Comparison of Doppler Indices and Elasticity Median Stiffness Between Study Groups

Variables	Subgroup	Group		Total	P value
		Group A No. (%)	Group B No. (%)		
Gravidity	1-2	4(8%)	16(32%)	20(20%)	**0.001***
	3-4	23(46%)	25(50%)	48(48%)	
	5+	23(46%)	9(18%)	32(32%)	
Parity	Nulliparous	0(0%)	11(22%)	11(11%)	**0.0001***
	1-2	20(40%)	29(58%)	49(49%)	
	3+	30(60%)	10(20%)	40(40%)	
Abortion	No	33(66%)	30(60%)	63(63%)	0.8
	1	13(26%)	15(30%)	28(28%)	
	2+	4(8%)	5(10%)	9(9%)	
Type of labour	Vaginal	0(0%)	31(62%)	31(31%)	**0.0001***
	CS	50(100%)	19(38%)	69(69%)	

Parameters	Group		P value
	Group A Mean±SD	Group B Mean±SD	
S/D U.A	2.6±0.3	2.5±0.3	0.07
PI	1.1±0.1	1.1±0.1	0.2
RI	0.6±0.05	0.6±0.05	0.07
E median (KPa)	7.8±2.4	3.1±0.2	**0.0001***

Regarding Doppler findings difference between study groups, there was no significant difference between PI, RI or S/D ratio of the two groups, as p value >0.05. While There was high significant difference between median elasticity value of Placental accreta spectrum with higher mean ±SD among group A 7.8±2.4 KPa vs 3.1±0.2 KPa in group B, p value <0.001, as shown in table 3-3.
* The result was significant at P-value <0.05, S/D U.A; systolic/diastolic of the umbilical cord artery, PI; Doppler pulsatility index, RI; resistive index E median; median elasticity.

There was no significant difference between the two groups concerning gestational age (GA) and fetal weight. However, there was a high significant difference in neonatal Apgar scores (table 3.4).

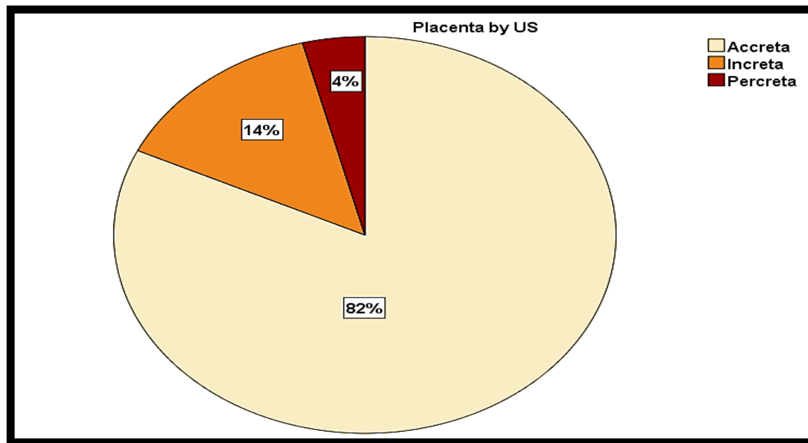
Table (3-4): Comparison of Neonate Characteristics Between Two groups

	Group		P value
	Group A Mean±SD	Group B Mean±SD	
Gestational Age (weeks)	38.6±1.1	38.2±1.1	0.07
Fetal Weight (g)	3223.4±193.7	3281.2±123.8	0.07
Apgar Score	6.9±1.1	8.04±1.1	**0.0001***

*** The result was significant at P-value <0.05**

Regarding distribution of Placental Adhesion grades by ultrasound, 41 (82%) of the placental Adhesion cases identified in this study were placenta accreta, 7 (14%) were placenta increta, and 2 (4)% were placenta percreta as shown in figure 3-1

Figure (3-1): Distribution of Placental Adhesion grades.



In figure (3-2), there was no significant difference between the grades of placental Adhesion concerning neonatal Apgar scores. However, there was a high significant difference in median elasticity (E median) values among the placental adhesion types.

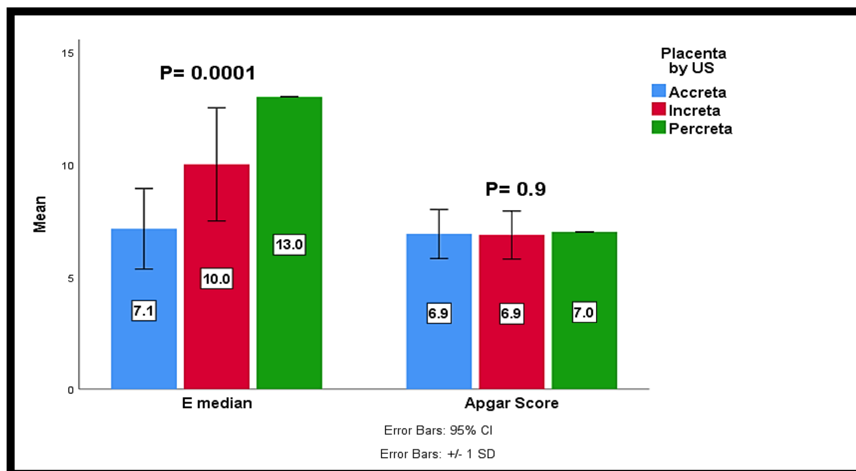
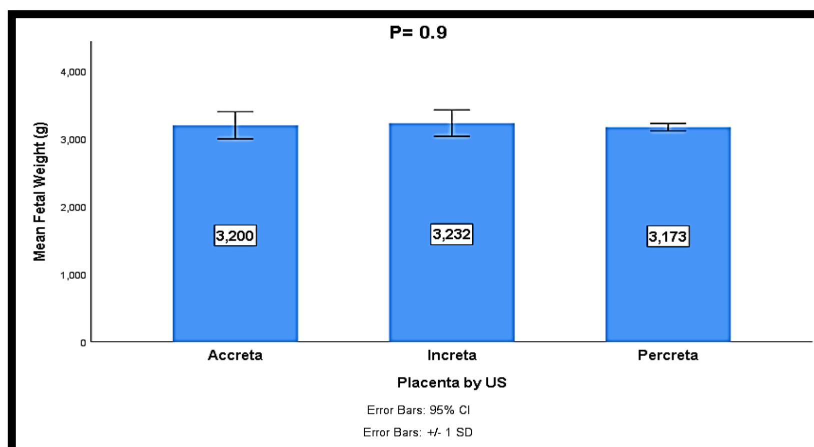


Figure (3-2): Comparison of mean E median and Apgar score according to the grades of *placental invasion* by US.



Regarding fetal weight and placental adhesion grades, there was no significant difference in fetal weight between the different grades of placental Adhesion. As shown in figure 3-3

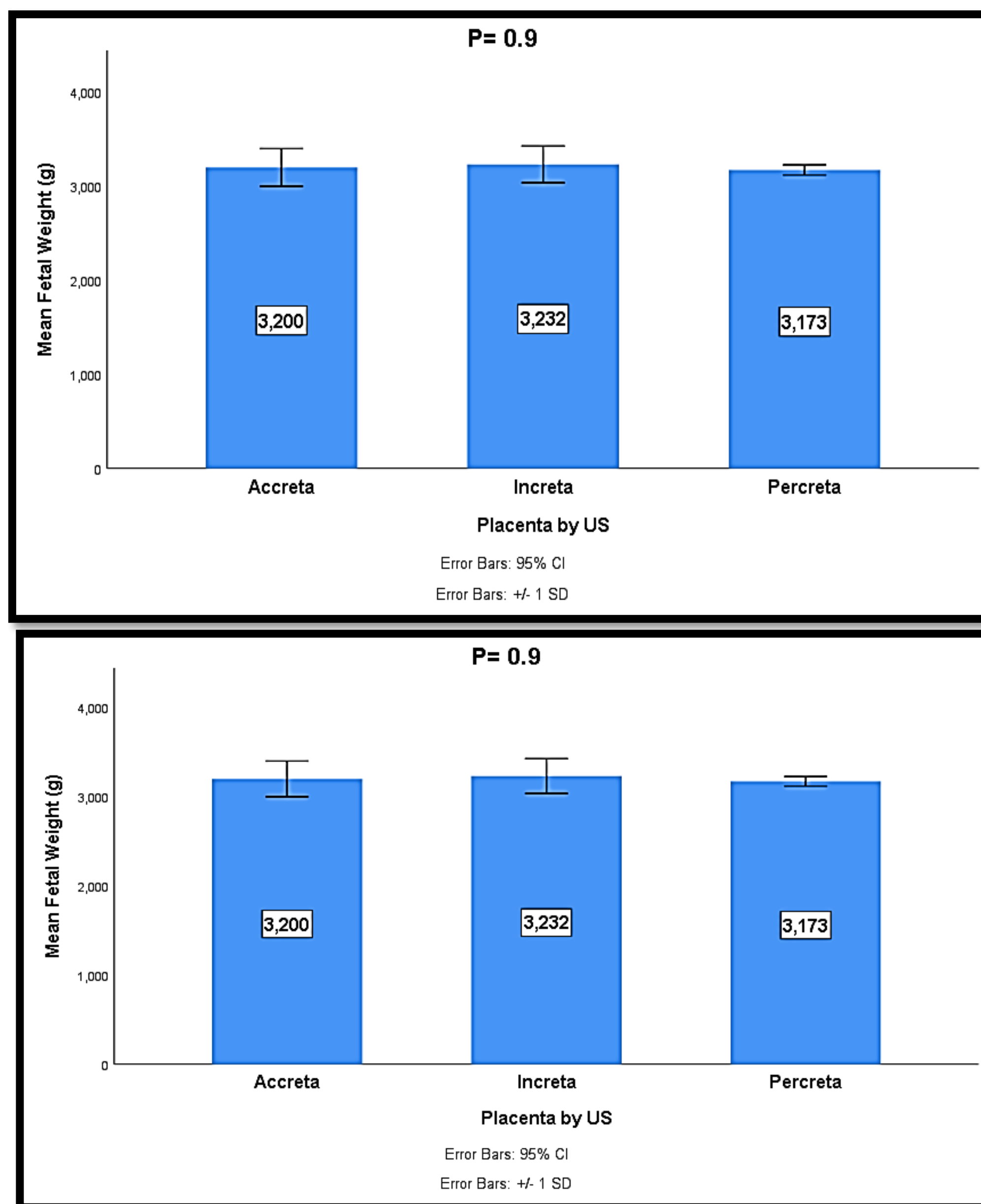


Figure (3-3): Comparison of Mean Fetal Weight (g) According to the Grade of Placenta by US.

The results indicate a highly significant difference in the median elasticity (E median) values among the two groups based on operative findings. The E median values increase progressively from normal cases to accreta, increta, and percreta cases. Statistical analysis confirms significant differences between normal cases and each abnormal group (accreta, increta, and percreta), as shown in table (3-5).

Table (3-5): Comparison of E median according to operative findings

Placenta	No.	Mean±SD	P value ANOVA	Normal vs Accreta	Normal vs Increta	Normal vs Percreta
Normal	55	3.3±0.6	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Accreta	35	7.2±1.4				

Increta	8	10.9±1.6				
Percreta	2	13±0.001				
Total	100	5.5±2.9				

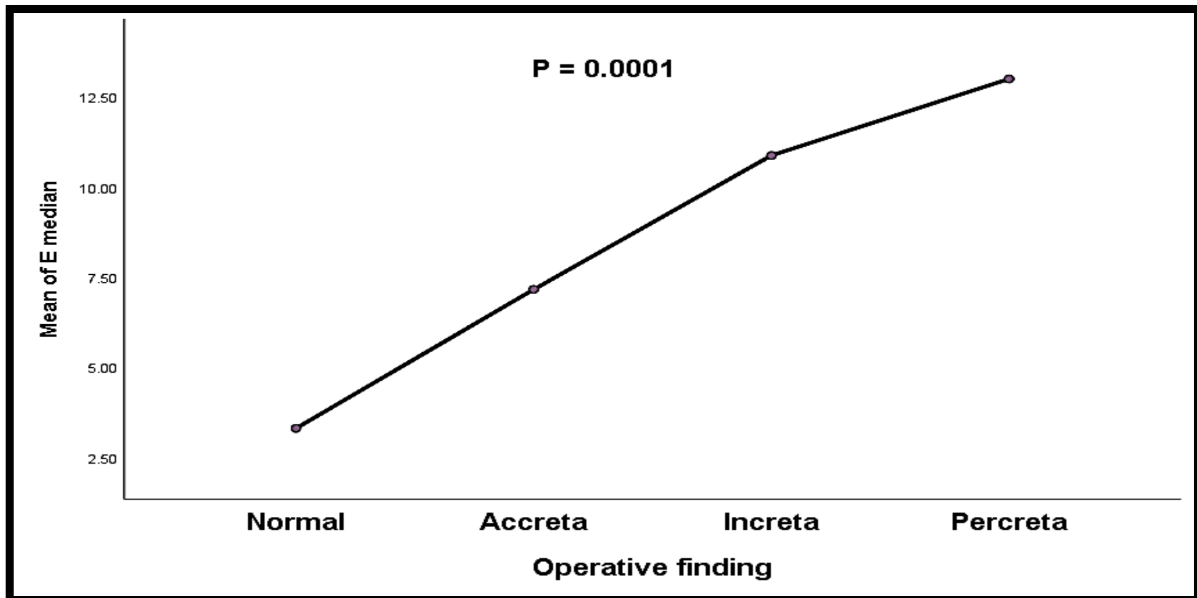


Figure (3-4): Comparison of E median according to placental operative findings

The figure above highlights that in normal control cases, the median elasticity (E median) was below 5 kPa. In cases of increta, it increased to approximately 7 kPa, while in percreta cases, it raised around 12 kPa.

There was a high level of agreement between ultrasound (US) and operative findings for normal placentas (90.9%), placenta accreta (91.4%), and placenta percreta (100%). However, there was moderate agreement for placenta increta, with notable misclassification between increta and accreta cases. Overall, the significant P-value (0.0001) indicates a strong correlation between US and operative findings, confirming the reliability of US in diagnosing placental Adhesions, though challenges remain in differentiating between accreta and increta as shown in table (3-6).

Table (3.6): Comparison of US and Operative Findings for Placental Adhesion

		Operative finding				Total
		Normal No.(%)	Accreta No.(%)	Increta No.(%)	Percreta No.(%)	
Placenta by US	Normal	50(100%)	0(0%)	0(0%)	0(0%)	50(100%)
	Accreta	5(12.5%)	32(78%)	4(9.8%)	0(0%)	41(100%)
	Increta	0(0%)	3(42.9%)	4(57.1%)	0(0%)	7(100%)
	Percreta	0(0%)	0(0%)	0(0%)	2(100%)	2(100%)
Total		55(55%)	35(35%)	8(8%)	2(2%)	100(100%)
P value = 0.0001						

Regarding diagnostic accuracy, ultrasonography is highly effective for diagnosing placenta accreta and percreta, while it shows moderate sensitivity for placenta increta. High specificity across all types indicates its reliability in ruling out false positives, as shown in table 3-7.

Table (3-7): Diagnostic Validity of Ultrasonography Compared to Operative Findings.

	TP	FP	TN	FN	SN	SP	PPV	NPV	Accuracy
Accreta	32	9	56	3	91.4%	86.2%	78%	94.9%	88%
Increta	4	3	89	4	50%	96.7%	57.1%	95.7%	93%
Percreta	2	0	98	0	100	100	100	100	100%

4. Discussion

Placenta previa-accreta may cause structural abnormalities that may affect placental stiffness.[(14)] Morbidly adherent placenta (previa-accreta) is the spectrum of abnormal implantation of the placenta into the uterine wall.[(15)] Placenta accreta spectrum (PAS) is a serious complication of pregnancy which can cause both fetal and maternal morbidity as it can lead to serious complications such as unplanned surgery, massive bleeding, peripartum hysterectomy, and mortality if not diagnosed early in Prenatal period.[(1)] Therefore, prenatal diagnosis of placenta accreta is vital to provide an effective management to minimize the life-threatening complications that is associated with placenta accreta. SWE is a new US technique used to gain information about the elasticity of soft tissues. Evaluation of placental elasticity may facilitate the diagnosis of placenta previa and accreta.[(14)]

In the current study, pregnant ladies with PAS were slightly older age than control group, this agree with Dokumaci *et al*., 2022[(16)] in which the mean maternal age was 34.74±6 in PAS vs 32.8±4.33 in control group, this may be due to that older woman may experience more complications in pregnancy, including PAS which is may be due to physiological changes in both the uterus and placenta with aging process.[(17)]

Regarding DM, HTN status and liquor status, no significant difference and no previous study about this relation, as DM and HTN can affect pregnancy outcomes for example preeclampsia, their affect on placental adhesion disorders is not identified yet as placental adhesion disorders are more linked to factors like uterine scar and previous CS than vascular or metabolic conditions.[(17)]

Regarding gravity and parity, the current study showed a significant correlation with placenta adhesion disorders, this disagree with Dokumaci *et al*., [(16)] who reported non-significant correlation as multiparity consider as a risk factor for PAS. Although curettage consider as a risk factor for PAS.[(17)] There was non-significant correlation with the abortion in the current study this could be due to limitations in study design, or differences in the population studied. To clarify this relationship, larger studies with detailed data on the type, number, and timing of curettage procedures would be needed.

Regarding type of delivery, cesareans-section were highly associated with placental adhesion disorders and this agrees with American College of Obstetricians and Gynecologists, the most common risk factor for PAS is a previous CS, with the incidence of placental adhesion disorders elevates with the number of previous CS. [(4,17).]

Regarding Doppler findings difference between study groups, there was non-significant relationship as the Doppler US of the umbilical artery primarily assesses fetal circulation and placental vascular resistance as a whole but does not directly measure abnormalities in placental adhesion or invasion.[(18)]

The current study demonstrated significantly higher placental stiffness using SWE in Group A pregnancy (placental adhesion group), and this agree with Davutoglu *et al.,*[(9)] and Dokumaci *et al*.,[(16)] studies, they reported that the mean placental elasticity (stiffness) values measured in pregnant ladies with PAS were higher in comparison to normal pregnant Ladies. This can explain by abnormal invasion of the placenta as in PAS, the placenta abnormally invades the myometrium. This leads to reduced decidual formation and altered tissue architecture,
resulting in increased stiffness at the placental attachment site.

Furthermore; PAS is often associated with areas of fibrosis and scarring in the myometrium due to prior CS or curettage. These fibrotic changes make the tissue less elastic and more resistant to deformation.[17]
There was no significant difference between the two groups concerning gestational age (GA); concomitant with Dokumaci *et al.,*[16] and fetal weight concomitant with Davutoglu *et al* study[9] as PAS primarily affects the local area of placental attachment rather than the overall placental function, and most pregnant ladies with PAS had planned CS delivery.[17]
Regarding Apgar score, there was significant difference between the two groups and this disagree with Davutoglu *et al* [9] this could be due to variety of factors like the severity of PAS patients, intra-partum complications, or differences in neonatal care.
The median elasticity value was significantly higher in cases with detected invasion (7.8±2.4) compared to control group (3.1±0.2), this agree with Cim *et al* study in 2018[19] who found significantly higher shear wave velocities in cases with detected invasion compared to non-invasive cases. The E median values increase progressively from normal cases to accreta, increta, and percreta cases. To our knowledge, this is the first study to evaluate the E median in each type of placenta-myometrial invasion, using the SWE imaging modality in pregnant women with placenta-myometrial invasion.
In the current study, sensitivity (SN) of US was high for diagnosing placenta accreta (SN 91.4%) and percreta (SN 100%), while it shows moderate sensitivity for placenta increta (SN 50%). High specificity(SP) across all types, placenta accreta (SP 86.2%) , increta (SP 96.7%) and percreta (SP 100%) indicates its reliability in ruling out false positives, this was in agreement with Abdel-Hafeez *et al* study in 2021[20] who reported US sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and diagnostic accuracy of 89.5%, 96.8%, 94.4%, 93.8% and 94.0% respectively, and concomitant with Dokumaci *et al* study in 2022(35) who reported US sensitivity and specificity of 85.7% and 88.6% respectively, moreover this study agrees with Hong et al study in 2022 that showed that the pooled sensitivity in detecting the placenta accrete was 94.4%, 100% for placenta increta, 86.5% for placenta percreta, and corresponding pooled specificity was 98.8%, 97.3%, and 96.8%, respectively .
There was a high level of agreement between ultrasound (US) and operative findings for normal placentas (90.9%), placenta accreta (91.4%), and placenta percreta (100%). However, there is moderate agreement for placenta increta, with notable misclassification between increta and accreta cases...

REFERENCES

1. Bowman ZS, Kennedy AM.Sonographic Appearance of the Placenta. Current Problems in Diagnostic Radiology. 2014;43(6):356–73.

2. Holzman J, Žalud I, Bartholomew M, Kurjak A, Chervenak F. Ultrasound of the Placenta. Donald School Journal of Ultrasound in Obstetrics and Gynecology. 2007;1(4):47-60.

3. Silver RM, Landon MB, Rouse DJ. Maternal morbidity associated with multiple repeat cesarean deliveries. Obstet Gynecol. 2006;107(6):1226-32.

4. American College of Obstetricians and Gynecologists. Placenta accreta. ACOG committee opinion no. 529. Obstet Gynecol. 2012;120:207–211.

5. AlıcıDavutoglu E, AriözHabibi H, Ozel A, Yuksel MA, Adaletli I, Madazlı R. The role of shear wave elastography in the assessment of placenta previa–accreta. The Journal of Maternal-Fetal & Neonatal Medicine. 2017;31(12):1660–2.

6. Chou MM, Ho ES, Lee YH. Prenatal diagnosis of placenta accrete by transabominal color Doppler ultrasound. Ultrasound Obstet Gynecol. 2000;15: 28-35.

7. DeLaat MW, Franx A, Bots ML, Visser GH, Nikkels PG. Umbilical coiling index in normal and complicated pregnancies. Obstet Gynecol. 2006;107:1049-55.

8. Yuksel MA, Kilic F, Kayaibi A. Shear wave elastography of placenta in patients with gestational diabetes mellitus. J ObstetrGynaecol. 2016;36:585–588.

9. Spiliopoulos M, Kuo CY, Eranki A. Characterizing placental stiffness using ultrasound shear-wave elastography in healthy and preeclamptic pregnancies. Arch Gynecol Obstet. 2020;302(5):1103–12.

10. Edwards C, Cavanagh E, Kumar S. Relationship between placental elastography, maternal pre-pregnancy body mass index and gestational weight gain. Placenta. 2022;121:1–6.

11. Altunkeser A, Alkan E, Gunenc E. Evaluation of a healthy pregnant placenta with shear wave elastography. Iran J Radiol. 2018;16:e68280

12. McClure EM, Saleem S, Goudar SS. The causes of stillbirths in South asia: results from a prospective study in India and Pakistan (PURPOSe) [article. Lancet Glob Health. 2022;10(7):970–977

13. Phipps EA, Thadhani R, Benzing T. Pre-eclampsia: pathogenesis, novel diagnostics and therapies [review]. Nat Rev Nephrol. 2019;15(5):275–289.

14. American Institute of Ultrasound in Medicine. AIUM practice guideline for the performance of obstetric ultrasound examinations. J Ultrasound Med. 2013;32(6):1083-101.

15. Akbas M, Koyuncu FM, Artunc-Ulkumen B. The relation between second-trimester placental elasticity and poor obstetric outcomes in low-risk pregnancies. J Perinat Med. 2021;49(4):468–473

16. Dokumaci DS, Uyanikoglu H. Shear-wave elastography for detection of placenta percreta: a case-controlled study. ActaRadiol. 2022;63(3):424–430.

17. American College of Obstetricians and Gynecologists. Placenta accreta. ACOG committee opinion no. 7. Obstet Gynecol. 2018;132: e259–75.

18. Nguyen NC, Evenson KR, Savitz DA, Chu H, Thorp JM, Daniels JL. Physical activity and maternal-fetal circulation measured by Doppler ultrasound. J Perinatol. 2013;33(2):87-93.

19. Cim N, Tolunay HE, Boza B, Arslan H, Ates C, İlik İ, et al. Use of ARFI elastography in the prediction of placental invasion anomaly via a new Virtual Touch Quantification Technique. J ObstetGynaecol. 2018 Oct;38(7):911-915.

20. Abdel Hafeez M, Hasan S, Eljazwi F, Mansour A. The Accuracy of Shear Wave Elastography in the Assessment of Placental Invasion in Women with Placenta Previa. Evidence Based Women's Health Journal. 2021; 11(3): 285-9.