Original Article

Radiological Features Of Pre-Eclampsia And Its Complications

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Abstract

Background: Pre-eclampsia, a human-pregnancy-specific disease defined as the occurrence of hypertension and significant proteinuria in a previously healthy woman on or after the 20th week of gestation, occurs in about 2–8% of pregnancies . It is the most common medical complication of pregnancy whose incidence has continued to increase worldwide, and It is associated with significant maternal morbidity and mortality, The diagnosis can still be made in the absence of proteinuria if the new-onset hypertension is accompanied by specific signs or symptoms of significant end-organ dysfunction.Doppler interrogation of the uterine artery typically demonstrates low end-diastolic velocity and an early diastolic notch .While in the second trimester there is decrease in the uterine artery vascular resistance represented by increased diastolic blood flow velocity and loss of the early diastolic notch by 22 weeks of gestation Elastography is the set of techniques by which tissue stiffness is estimated as a physical property termed the Young's modulus (E).the basis of elastography imaging depends on the deformation of the target lesion compared to the background tissue. As softer tissue deform to a greater degree when compressed and therefore show greater or higher strain compared to the background tissue In the first trimster of the normal pregnanacy.

Keywords: Pre-eclampsia

INTRODUCTION

Pre-eclampsia, a human-pregnancy-specific disease defined as the occurrence of hypertension and significant proteinuria in a previously healthy woman on or after the 20th week of gestation, occurs in about 2–8% of pregnancies. It is the most common medical complication of pregnancy whose incidence has continued to increase worldwide, and It is associated with significant maternal morbidity and mortality, the diagnosis can still be made in the absence of proteinuria if the new-onset hypertension is accompanied by specific signs or symptoms of significant end-organ dysfunction **(1).** Pre-eclampsia is responsible for over 70000 maternal deaths and 500000 fetal deaths worldwide every year. Although delivery can resolve most signs and symptoms; but preeclampsia can persist after delivery and, in some cases can develop de novo in the postpartum period **(1).**

1- ***Ultrasound***:

(A) Early detection (Uterine Artery Doppler)
(B) In preeclamptic pregnanacies

- ***Abnormal Doppler Indices.***
- ***Intra-Utrine Growth Restriction (IUGR).***
- ***Placental Abrubtion And Antenatal hemorrhage.***
- ***Features of HELLP syndrome.***

A- Early detection (Uterine Artery Doppler):

In the first trimester of the normal pregnancy; Doppler interrogation of the uterine artery typically demonstrates low end-diastolic velocity and an early diastolic notch .While in the second trimester there is decrease in the uterine artery vascular resistance represented by increased diastolic blood flow velocity and loss of the early diastolic notch by 22 weeks of gestation. These findings possibly reflects the second wave of trophoblastic invasion of spiral arteries which is completed between 16 and 18 weeks of gestation. In normal pregnancy the mean Pulsatility index (PI) in the right and left uterine artery are 1.09 and 0.81, with a range of 0.53 - 1.83 . The Resistive index (RI) has a mean of 0.59 and 0.65, with a range of 0.37-1.16 .Uterine artery PI and RI values continue to decrease with increasing gestational age secondary to a fall in impedance in uterine vessels **(2).**

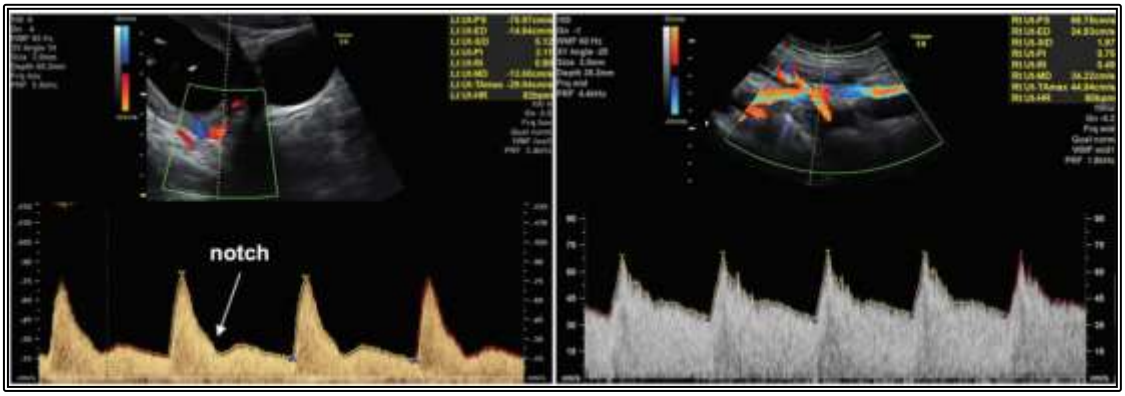

Figure 1 : *Doppler velocimetry of the uterine arteries showing a high resistance pattern with notching between the systolic and the diastolic components of the wave* ***(A),*** *characteristic of the first trimester, and a low resistance pattern* ***(B),*** *characteristic of the second trimester* **(2).**

While pregnancies that show persistent high resistance wave forms with early diastolic notches are at risk of preterm delivery, due to pre-eclampsia, abruption, and intrauterine growth restriction (IUGR), Mean pulsatility index (PI) values > 1.45 or bilateral early diastolic notches are considered abnormal **(3).**

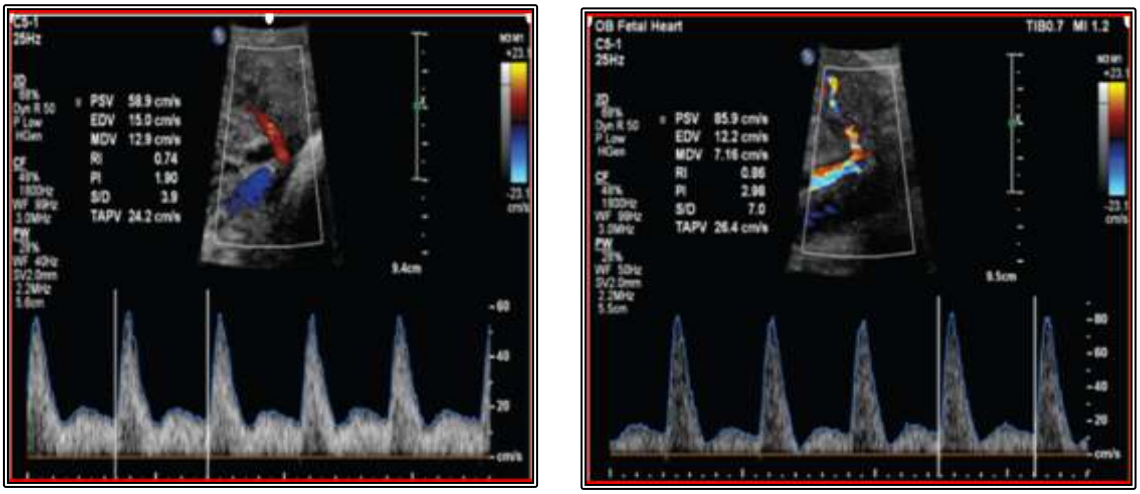

Figure 2:*Abnormal second trimester uterine artery Doppler waveforms on the right* ***(A)*** *and left* ***(B)*** *sides characterized by a mean PI of 2.44 and bilateral diastolic notches* **(3).**

These findings possibly reflects the inadequate trophoblastic invasion that is implicated in preeclampsia with Impaired development of the placenta that leads to persistant elevated resistance to blood flow in the uteroplacental circulation, abnormal waveform patterns of the uterine arteries on sonographic Doppler velocimetry evaluation and increased pulsatility and resistance indices seen .Therefore, this method could possibly be used as a screening test to identify pregnancies at increased risk of PE and Fetal Growth Restriction (FGR) , although the accuracy of this test as a standalone screening tool is poor, but if combined with maternal characteristics, maternal history and other biophysical and biochemical markers seems more promising **(3).**

In pre-eclamptic pregnancies :

❖ *Abnormal Doppler Indices*

1- The Umbilical Artery : is the first fetal vessel to be evaluated by doppler velocimetry. Flow velocity waveforms from the umbilical cord have a characteristic **saw-tooth appearance** of arterial flow in one direction and continuous umbilical venous blood flow in the other **(4)** With advancing gestation, umbilical arterial doppler waveforms demonstrate a progressive rise in the end-diastolic velocity and a decrease in the impedance indices (i.e. there is more diastolic flow as the fetus matures) so RI mean value decreases from 0.756 to 0.609 and PI mean value decreases from 1.270 to 0.967 **(4)**

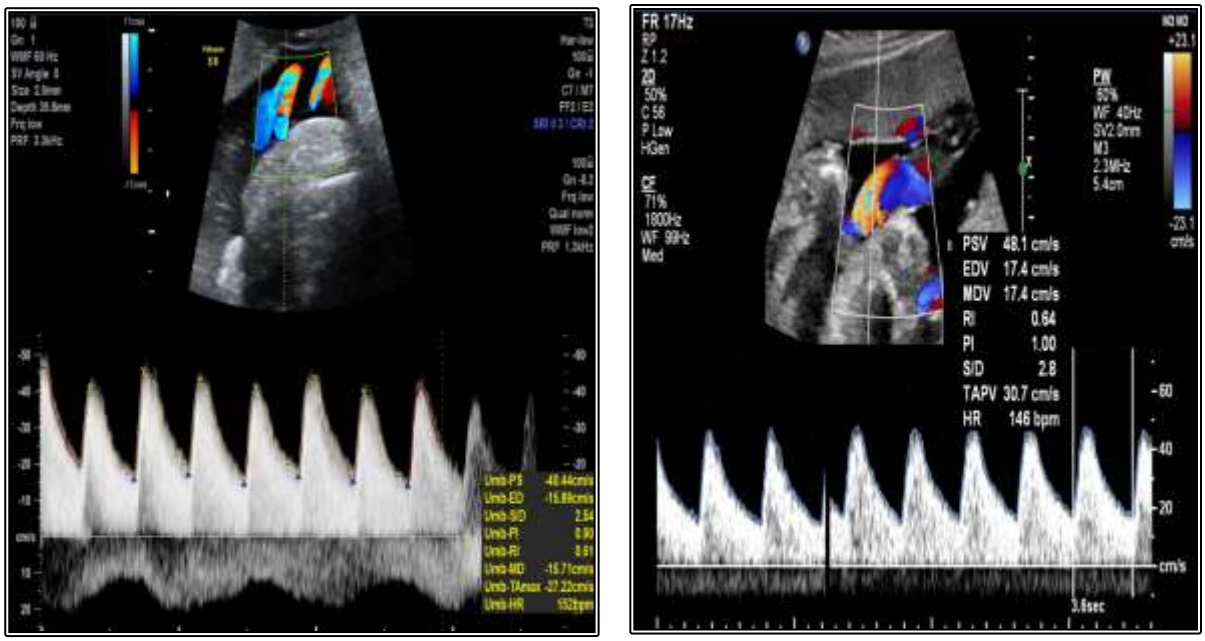

Figure 3: *Normal umblical artery doppler* **(5).**

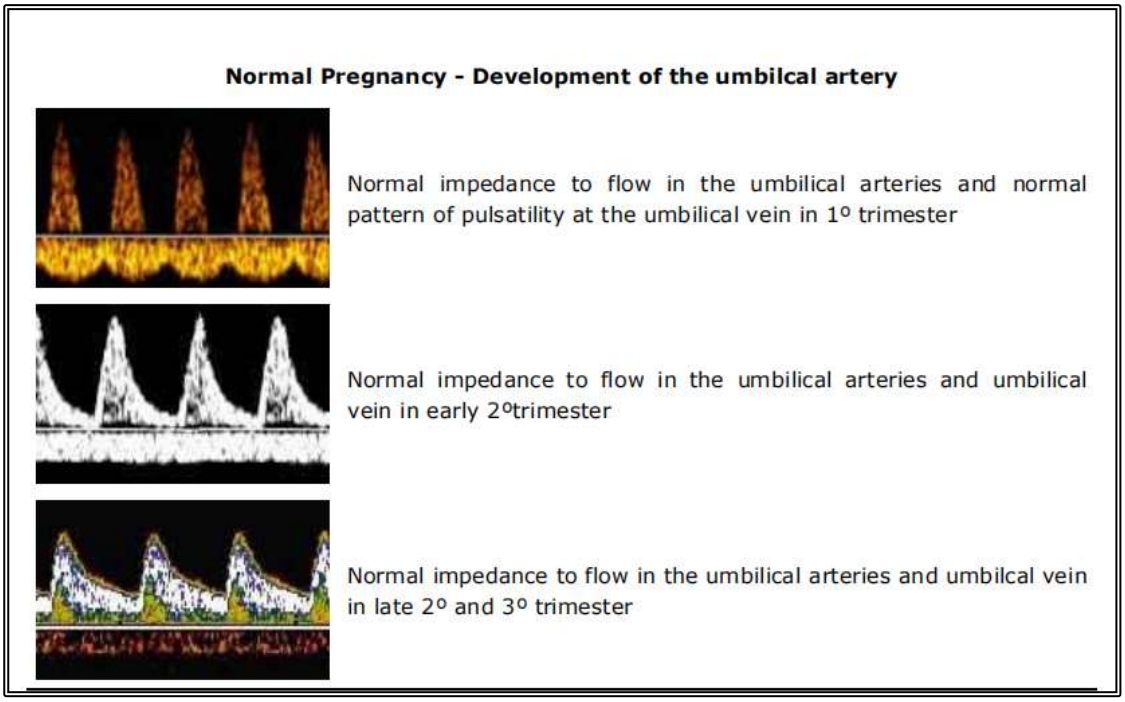

Figure 4 : *Normal development of the umblical artery doppler* **(4)**

In case of pre-eclampsia , the umbilical artery blood velocity waveform usually changes in a progressive manner from low diastolic flow to abscent diastolic flow then to reversed diastolic flow that correlates with severity of the placental insufficiency **(5).**

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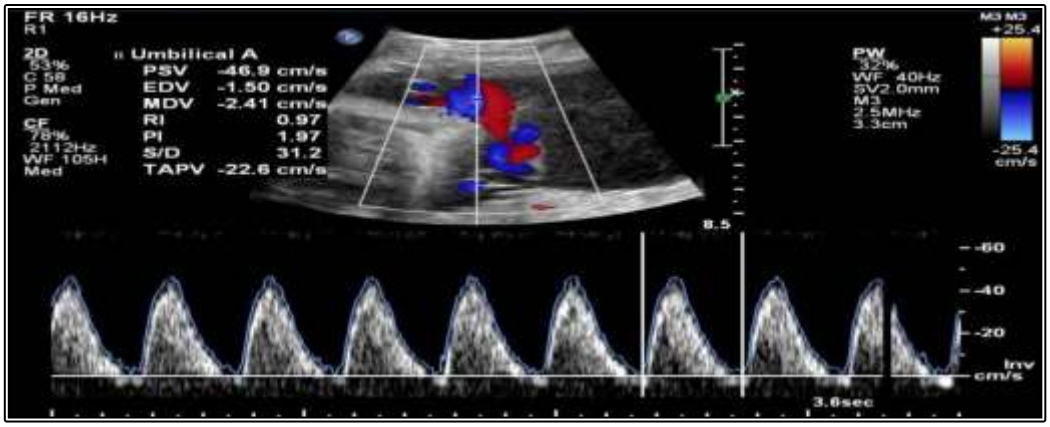

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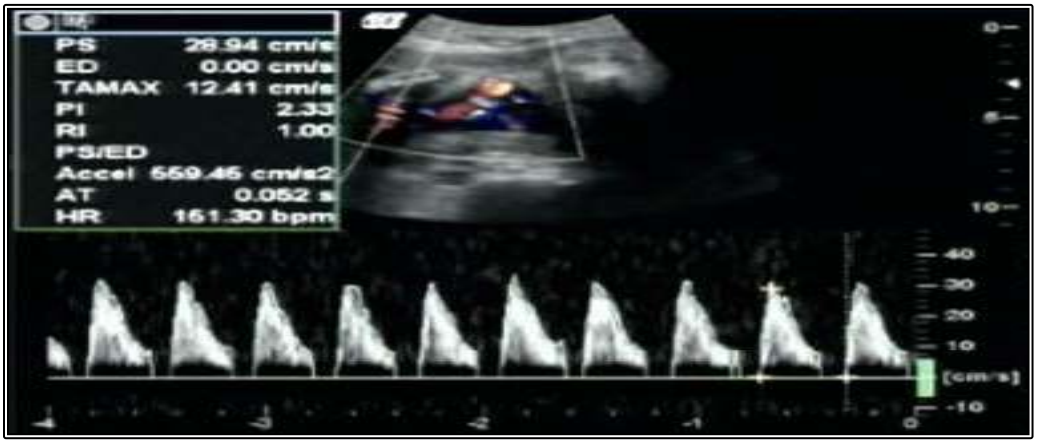

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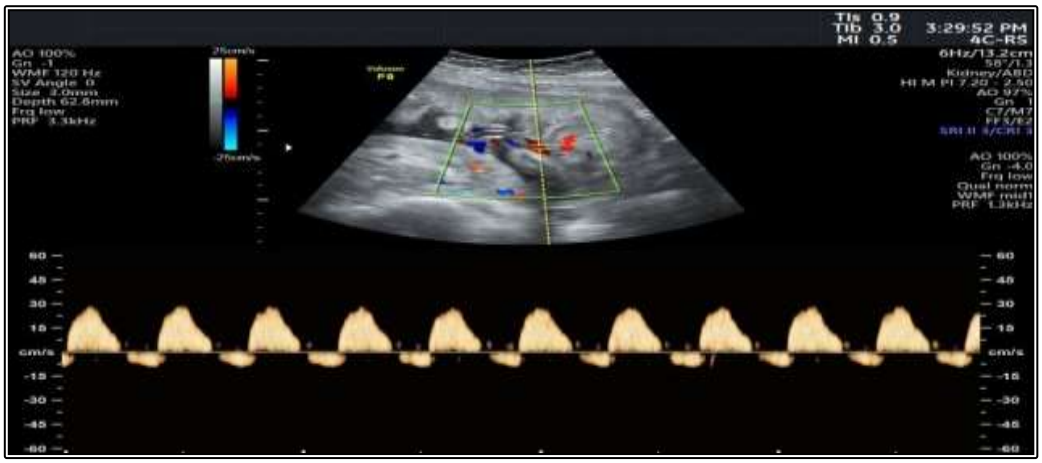
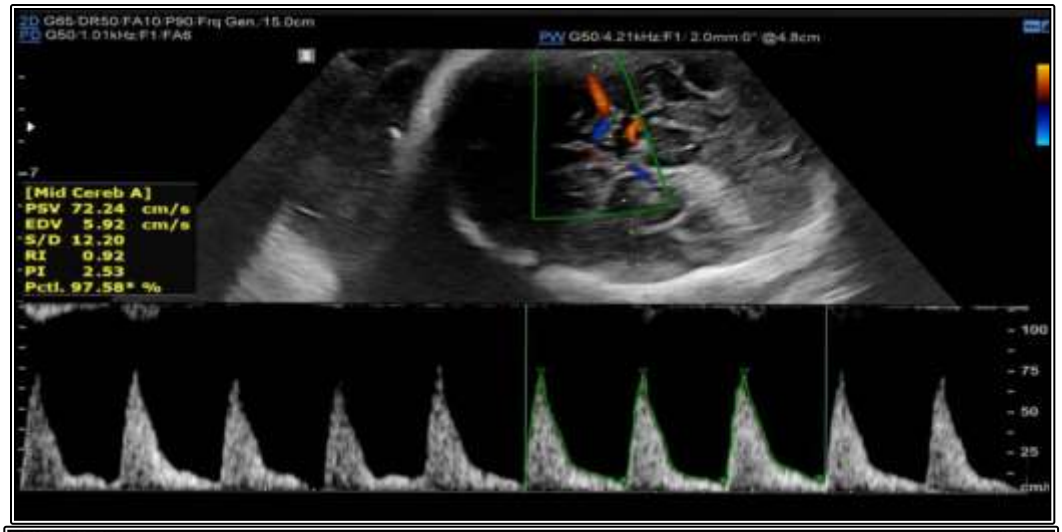


Figure 5 : *Abnormal UA Doppler trace with* ***(A)*** *low diastolic flow and high resistive index ,****(B)*** *absent diastolic flow and* ***(C)*** ***r****eversed diastolic* **(6).**

2- The Middle Cerebral Artery : is an important part of assessing fetal cardiovascular distress, fetal anemia or fetal hypoxia. in the normal situation the fetal MCA has a high resistance flow which means high systolic velocity with minimal or absent antegrade flow in fetal diastole **(7)**

A)



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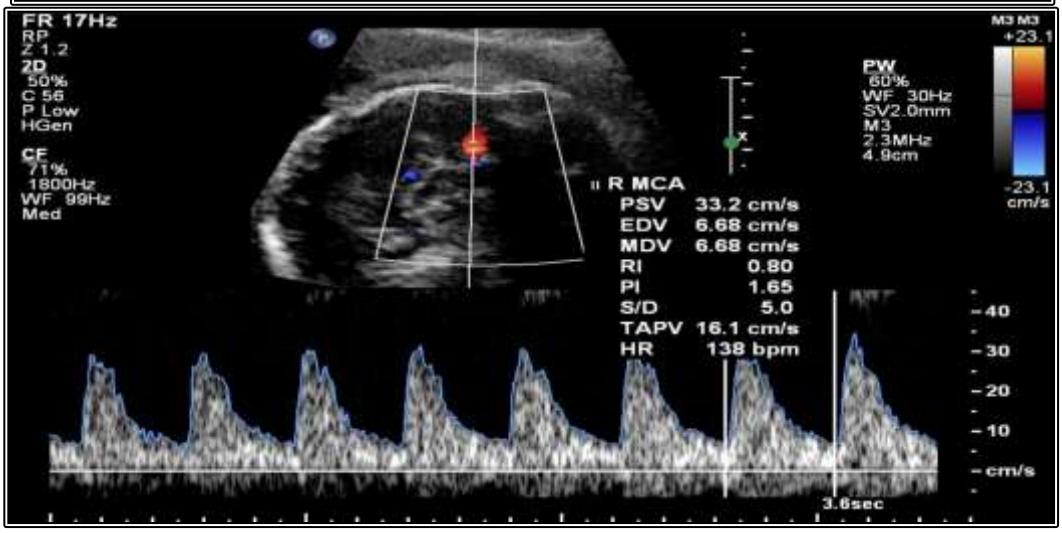
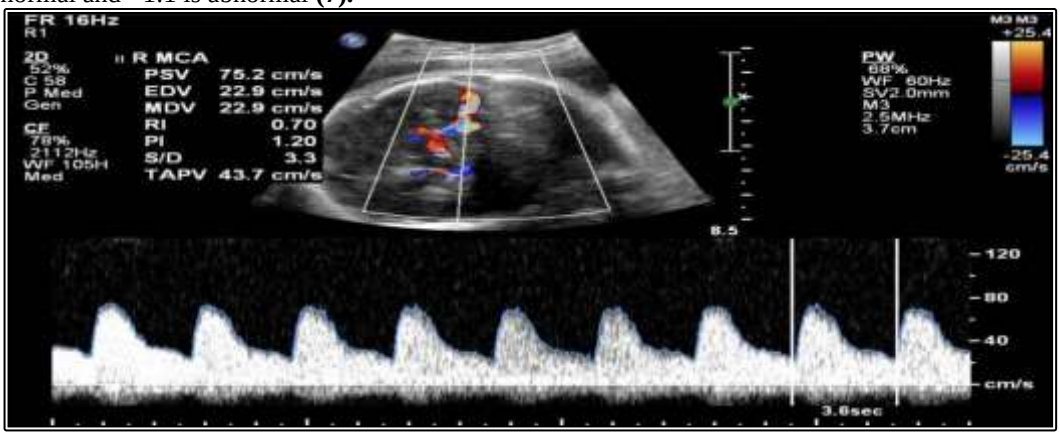


Figure 6: ***(A)*** *and* ***(B)*** *Normal MCA Doppler trace* **(7)**

The normal value of fetal MCA S/D ratio will vary by institution. A normal fetal MCA S/D ratio should always be higher than the umbilical arterial S/D ratio. The fetal MCA S/D ratio value will decrease as the pregnancy progresses **(6).** In pathological states as pre-eclampsia this can turn into a low resistance flow mainly as a result of the fetal head sparing theory . As in response to hypoxia, the fetus diverts blood flow to the brain, increasing the middle cerebral artery diastolic flow, thereby decreasing the pulsatility index and altering the ratio of the umbilical artery flow to the middle cerebral artery flow . So cerebro-placental ratio: >1:1 is normal and <1:1 is abnormal **(7).**

A)



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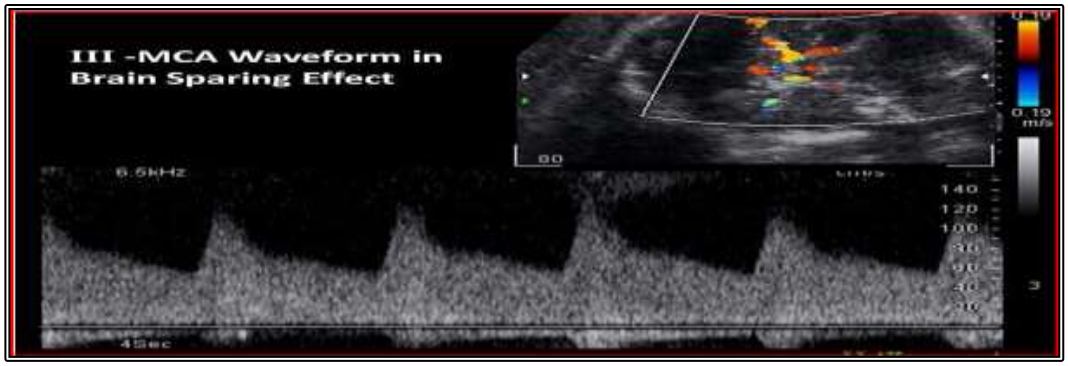


Figure 7: ***(A)*** *and* ***(B)*** *Abnormal MCA Doppler trace in sever pre-eclampsia with high diastolic flow in brain sparing effect* **(8)**

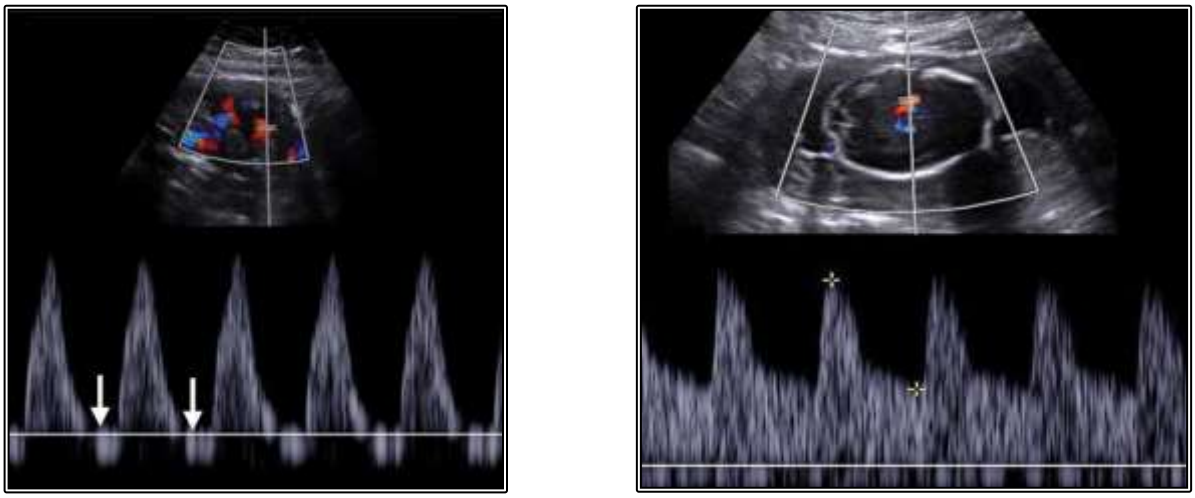


Figure 8: *Abnormal cerebroplacental ratio. (a) Color Doppler duplex US image of the umbilical artery shows reversed end-diastolic flow (arrows). (b) Color Doppler duplex US image shows that increased diastolic flow was present in the middle cerebral artery, indicating "head-sparing" flow* **(9)**

3- The Ductus Venosus : is used to assess cardiac strain in the second and third trimesters when there are concerns regarding intrauterine growth restriction (IUGR) or fetal cardiac compromise that may both occur in pre-eclampsia . The flow in the ductus venosus has a specific triphasic waveform where in a normal physiological situation flow should always be in the forward direction (i.e. towards the fetal heart) (81).
This triphasic waveform comprises of:

- ***S wave:*** *corresponds to fetal ventricular systolic contraction and is the highest peak*
- ***D wave****: corresponds to fetal early ventricular diastole and is the second highest peak*
- ***A wave:*** *corresponds to fetal atrial contraction and is the lowest point in the wave form albeit still being in the forward direction* **(10).**

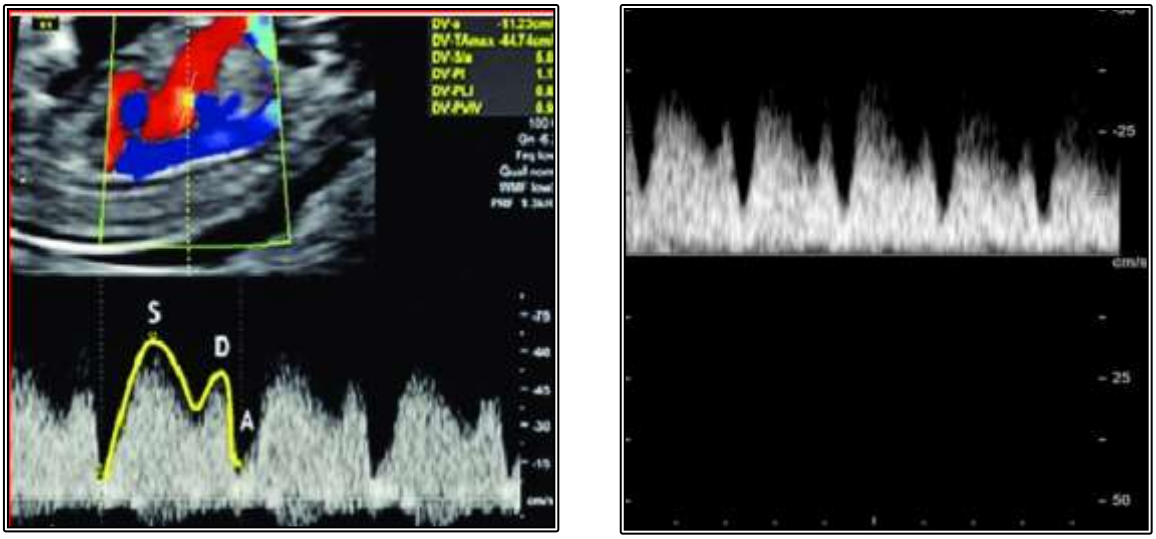
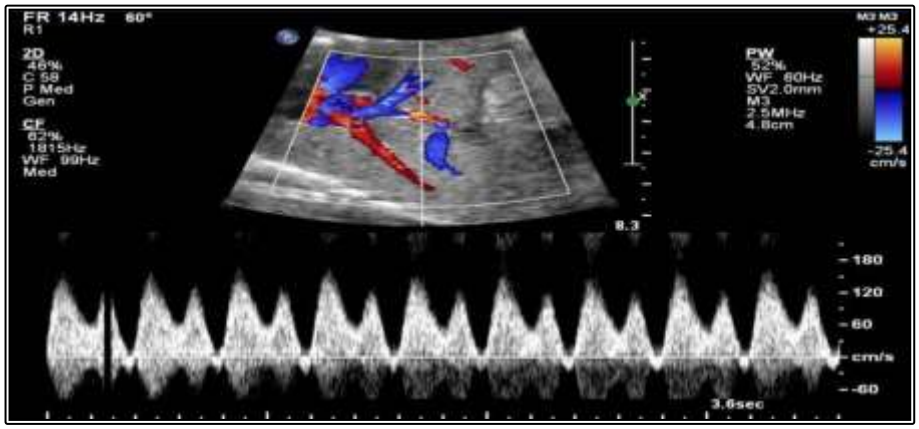


Figure 9: *Normal ductus venousus flow* **(11)**

When placental function is impaired, a larger percentage of umbilical vein blood flow is shunted to the left side of the heart (the head-sparing effect). This shunting decreases flow to the liver, impairing liver growth and limiting fetal weight gain .The parameters that influence cardiac function include afterload (increased placental resistance), myocardial performance (cardiomyopathy), and preload as in (the recipient twin in the twin-twin transfusion syndrome) **(12).** Decreased forward flow during atrial systole (diminished or reversed A wave) is the most sensitive finding when any one of these parameters is affected **(12).**

A)



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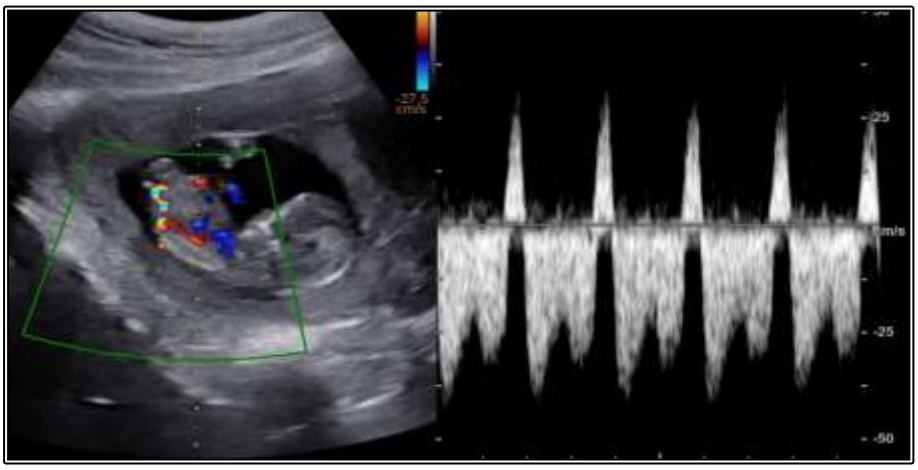


Figure 10: *Ductus venosus doppler abnormalities:* ***(A)*** *shows reversed A wave in sever IUGR ,* ***(B)*** *shows absent to reversed a wave in sever IUGR* **(12)**

❖ ***Intra-Uterine Growth Restriction (IUGR)***

Is defined as an estimated fetal weight (EFW) and/or abdominal circumference (AC) at one point in time during pregnancy being below 3rd percentile or EFW and/or AC below the 10th percentile for gestational age with deranged Doppler parameters **(13).**

<u>An IUGR can be broadly divided into two main types:</u>

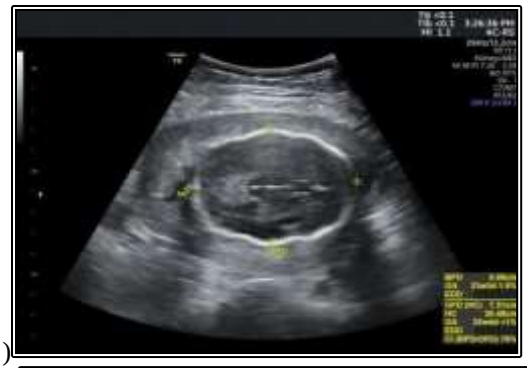
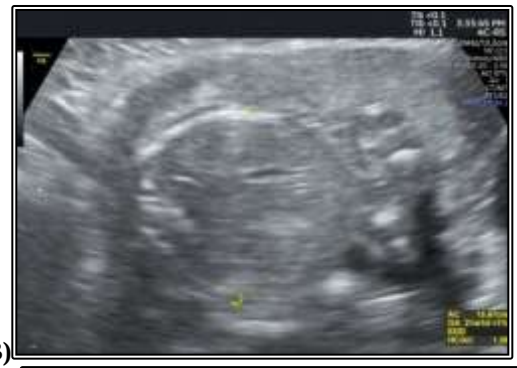
Type I: Symmetrical intrauterine growth restriction in which all fetal biometric parameters tend to be less than expected (below the 10th percentile) for the given gestational age. Both length and weight parameters are reduced
Type II: Asymmetrical intrauterine growth restriction in which some fetal biometric parameters are disproportionately lower than others, as well as falling under the 10th percentile. The parameter classically affected is the abdominal circumference (AC) .

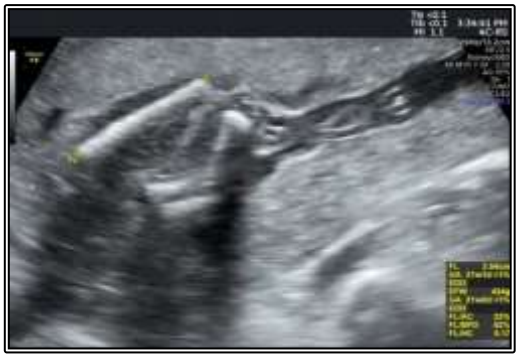
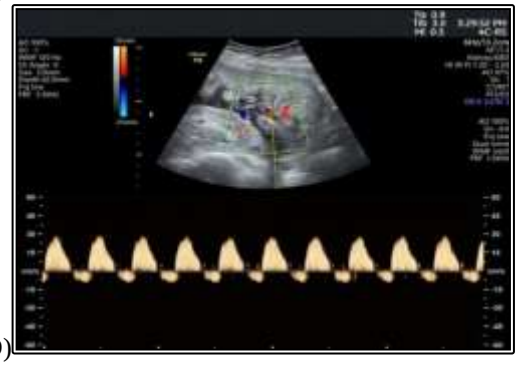
<u>Sonographic parameters include:</u>

❖ **Non-Doppler features:**

1. *Reduced abdominal circumference (AC) and/or EFW*
   AC and/or EFW <3rd percentile.
   AC and/or EFW <10th percentile with deranged Doppler parameters .
2. *Presence of oligohydramnios without ruptured membranes .*
3. *Increased head circumference (HC) to abdominal circumference (AC) ratio (in asymmetrical type) .*
4. *Advanced placental grade .*

❖ **Doppler features :** umbilical artery Doppler assessment with increased PI above 95th percentile and absent/reversed diastolic flow **(14).**

A)  **B)** 

C)  **D)** 

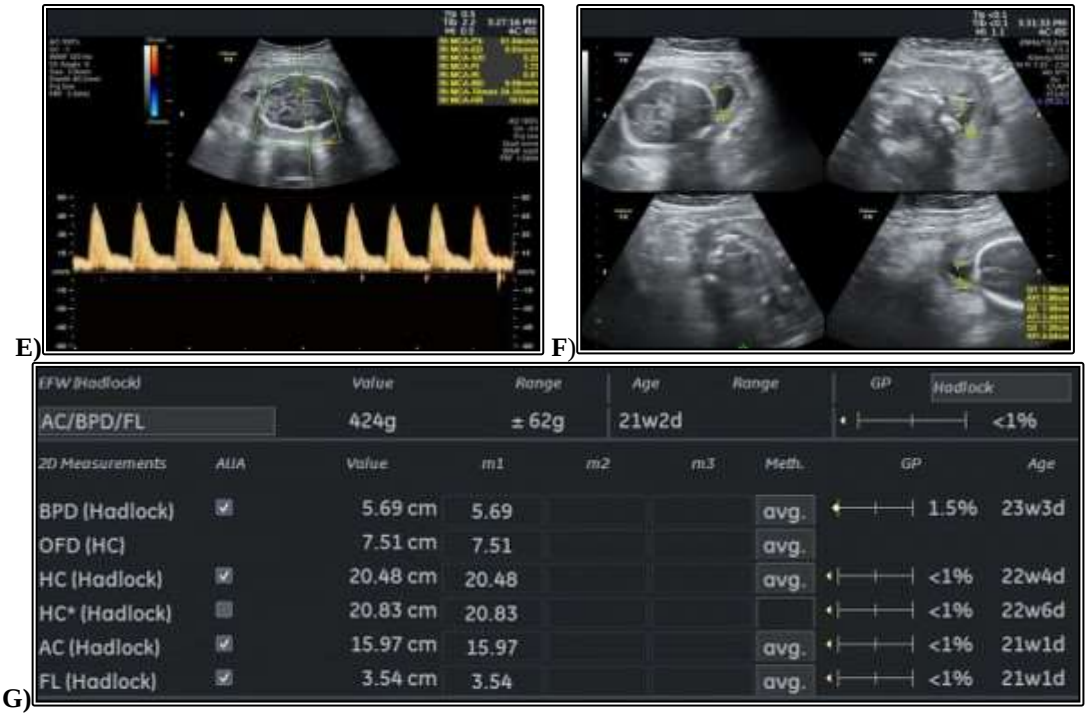


Figure 11: *A case of IUGR with the fetus mean gestational age is about 22 weeks, compared to gestational age by last menstrual period (25 weeks and 3 days), with* ***(A)****gestational age by Bi Parietal Diameter BPD=23w+3d* ***(B)*** *gestational age by Abdominal circumference AC= 21w+1d* ***(c)*** *gestational age by Femur Length FL=21w+1d* ***(D)*** *abnormal umbilical artery Doppler with reversal of diastolic flow , (E) normal middle cerebral artery Doppler for gestational age (F) shows oligohydramnios (G)increased HC:AC ratio and EFW<3rd percentile, suggestive of intrauterine growth restriction (13)*

❖ *Placental Abruption And Antepartum Hemorrhage*

Abruptio placentae is used to refer to partial or complete detachment of the placenta from the underlying myometrium before the expected delivery time. Placental abruption is more common after 16 weeks of gestation with the highest reported incidence for abruption is from 24th to 26th weeks of gestation, after which PA incidence drops with advancing gestational age , it include placental or periplacental hemorraghe **(15).**

Risk factors for placental abruption include : prior history of placental abruption , Preeclampsia and gestational hypertension (being the second most common cause after prior history of pre-eclampsia) other risk factors include smoking, multiparity, thrombophilia and premature rupture of membranes (PROM) **(15).**

Placental abruption is associated with maternal, fetal, and neonatal increased morbidity and mortality. **Maternal complications** are disseminated intravascular coagulopathy (DIC), uncontrolled blood loss, or risk of hysterectomy . **Fetal complications** include intrauterine growth restriction (IUGR), non-reassuring fetal heart rate (NFHR), and fetal demise. **Neonatal complications** include premature delivery and neonatal death **(16).**

Types of placental abruption: placental abruption can be classified based on the location of the hematoma as **Retroplacental** , **Preplacental** , and **Intraplacental (16).**

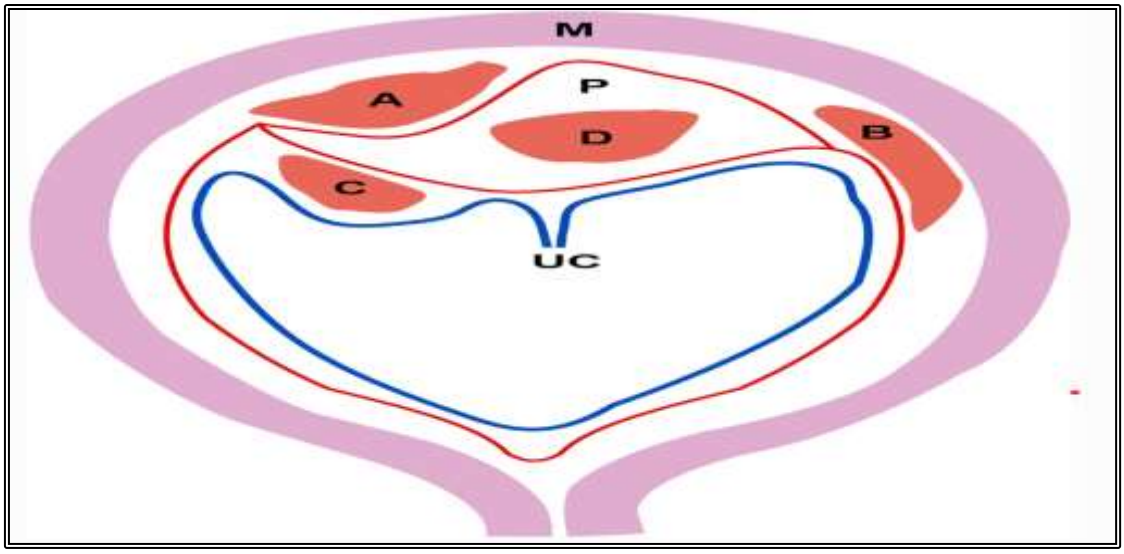


Figure 12: *Illustrative drawing of placental hematomas* ***(A)Retroplacental hematoma*** *is located behind the basal plate and elevates the placenta (P) from the underlying myometrium (M).* ***(B) Marginal subchorionic hematoma*** *is located peripherally behind the placental margin and extends behind the chorion.****(C) Preplacental hematoma*** *is located anterior to the placenta above the chorionic plate behind the amnion (blue line) and usually limited by the umbilicalcord(UC).****(D) Intraplacental hematoma*** *is bleeding inside the placenta (P).***(17).**

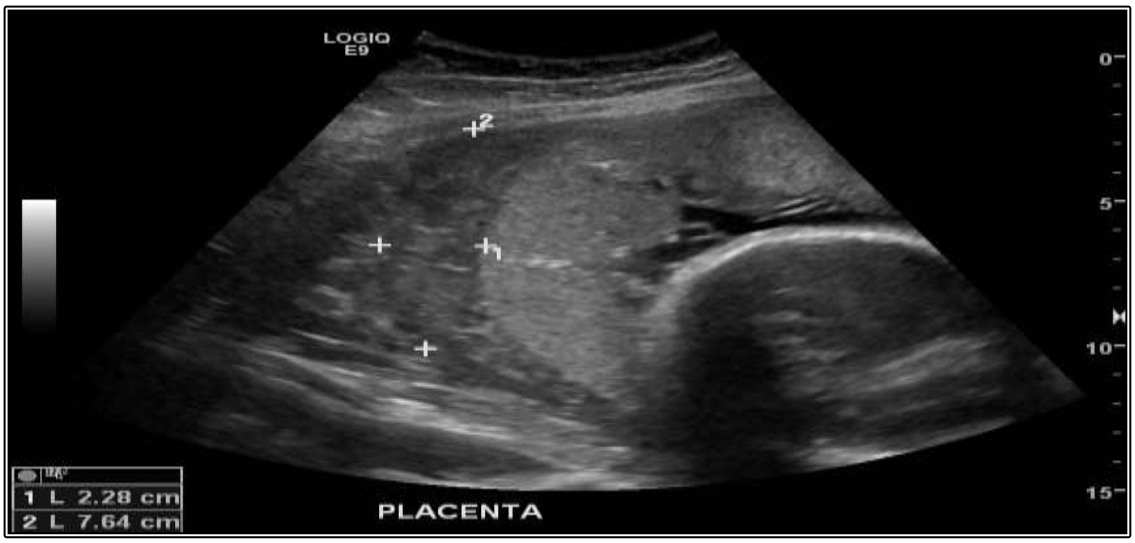


Figure 13: *Hypoechoic crescent of avascular, low echogenicity retroplacental hematoma between the placenta and uterine wall consistent with placental abruption (18***).**

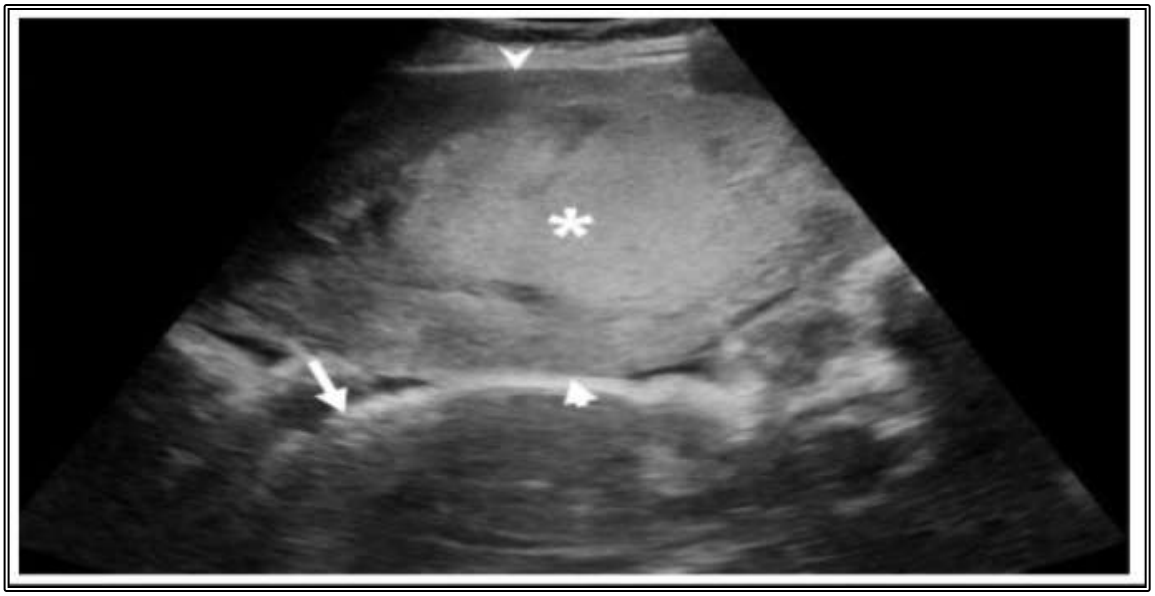


Figure 14: *Hyperechoic mass (asterisk) between the placenta (short arrow) and the uterus (arrowhead), which presented as a typical abruption* **(19).**

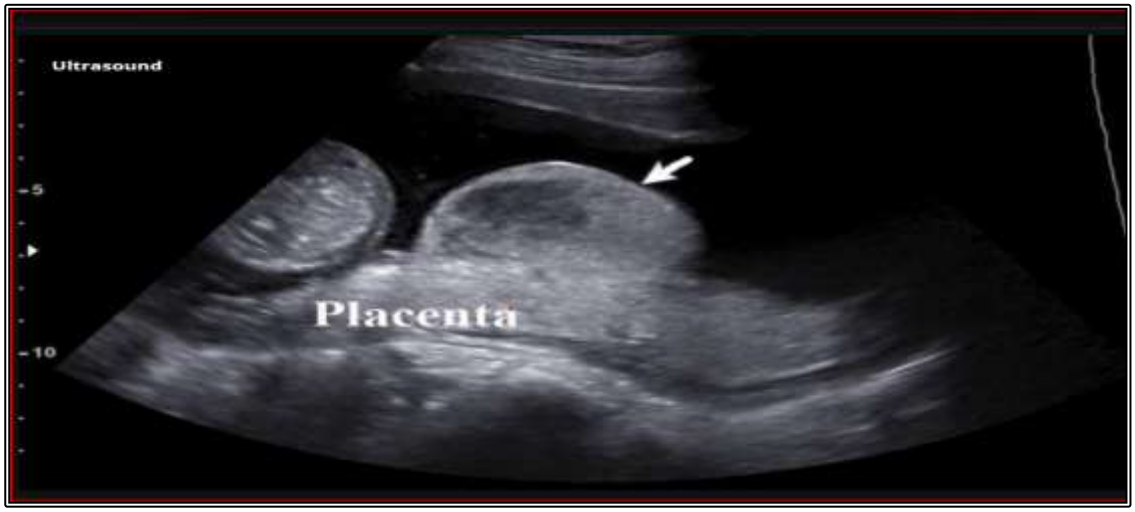


Figure 15 :*Preplacental hematoma* **(20).**

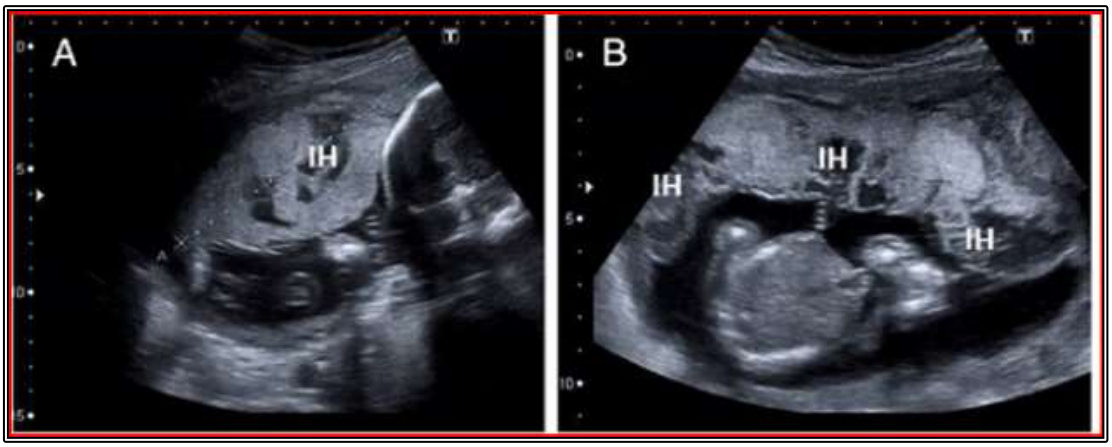


Figure 16:*inter placental hematoma (IH)* **(21)**

❖ ***Features of HELLP syndrome***

HELLP syndrome is a pregnancy-related condition and is an abbreviation for: **Haemolysis** , **Elevated Liver enzymes** and **Low Platelets** . It is considered a severe and life-threatening form of pre-eclampsia although it can occur without co-existing pre-eclampsia .The exact cause of HELLP syndrome is unknown. General activation of the coagulation cascade is considered to be the main underlying problem, leading to microangiopathic haemolytic anaemia and platelet consumption however other theroies are suggested as immune-mediated maternal acute rejection reaction to fetal antigens , placenta-mediated liver injury and systemic inflammatory response syndrome in the setting of pre-eclampsia (22).

The clinical presentation can be variable and can include malaise, epigastric and/or right upper quadrant pain, and nausea and vomiting. Some may have viral like symptom. Hypertension and proteinuria (classic symptoms of pre-eclampsia) may be absent or present (23).

Complications can include disseminated intravascular coagulation: reported to occur in ~30% of patients , hepatic infarction, hepatic hematoma , hepatic rupture and placental abruption with radiographic features general features predominantly involve hepatic sequelae : as hepatomegaly especially the right lobe , hemorrhage, subcapsular hematoma, rupture or hepatic infarction (24).

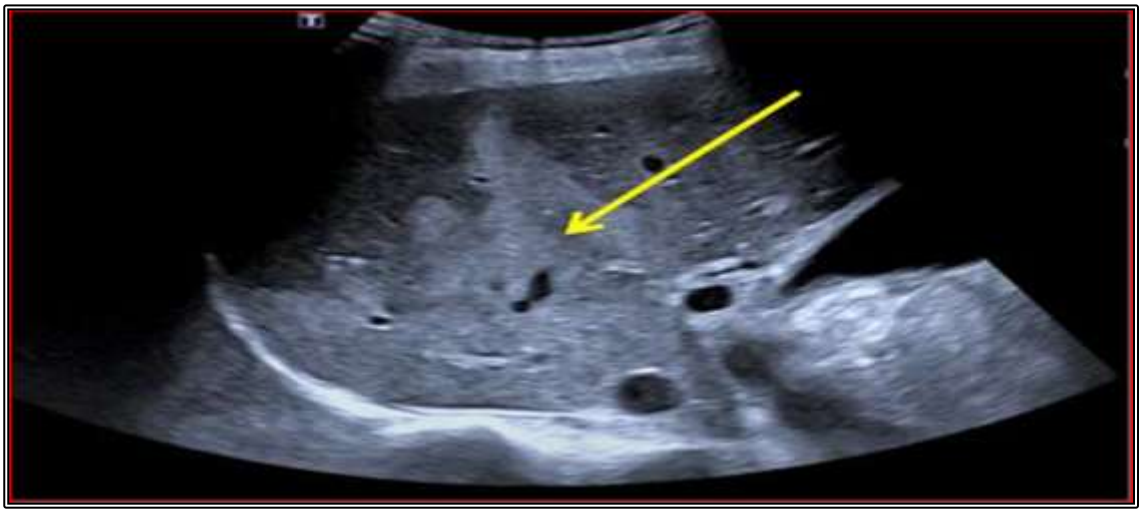


Figure 17 : *Ultrasound B-mode image of the right lobe of liver at day 3 post-partum demonstrating persisting geographic areas of increased parenchymal echogenicity (arrow)* **(25)**

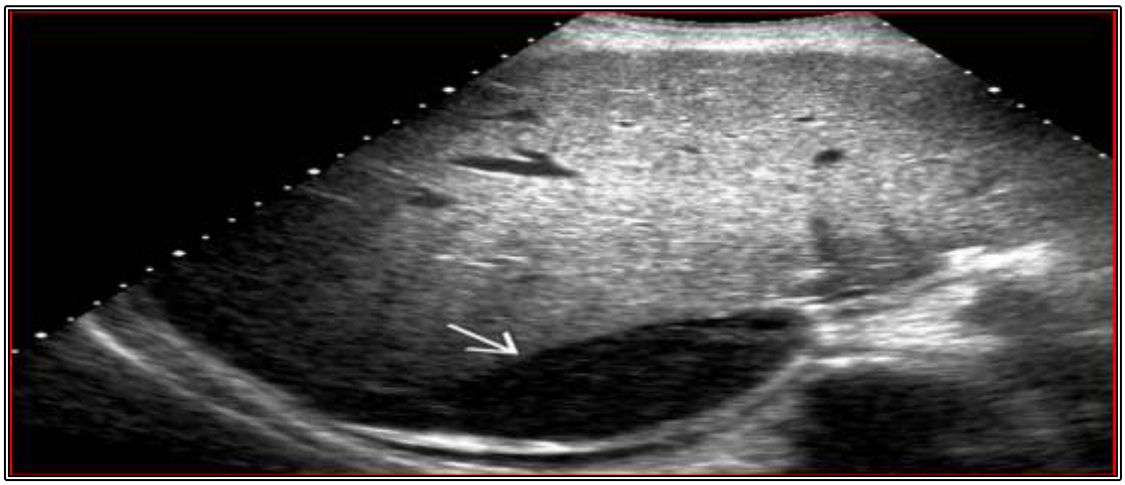


Figure 18:*39-year-old woman who presented with sharp RUQ and right pleuritic pain during her 3rd trimester of pregnancy.Longitudinal grayscale ultrasound image obtained shows the peripheral subcapsular hematoma* **(25)**

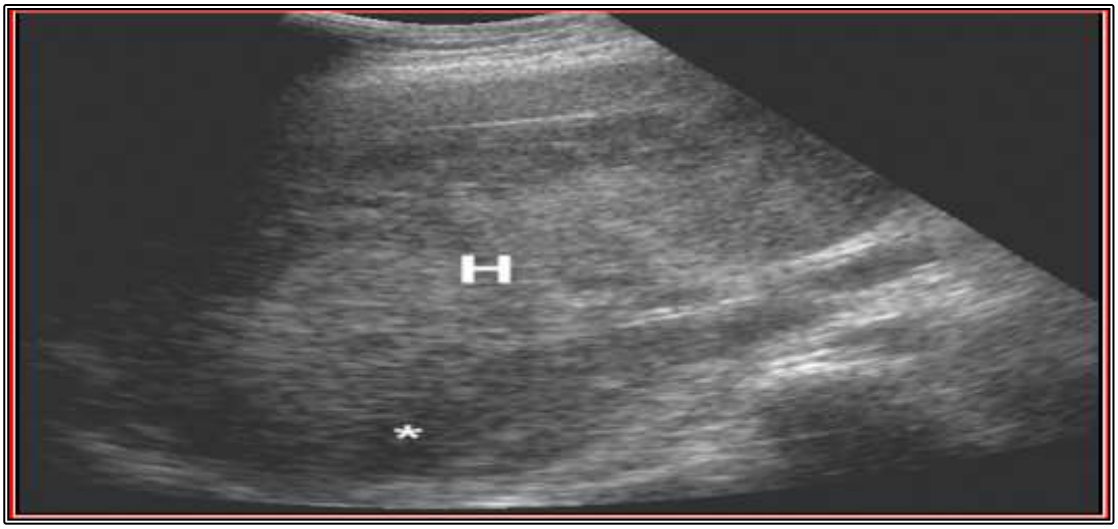


Figure 19 :*33-year-old woman with HELLP syndrome and liver rupture. A, Transverse sonogram of liver shows heterogeneity (H), which is representative of hematoma, involves right hepatic lobe and Perihepatic hematoma (asterisk) is slightly hypoechoic relative to liver* **(26).**

2- <u>Shear Wave Elastograhy of the placenta :</u>

Shear Wave Elastography is a new technology for evaluation of soft tissue elasticity, which gives a broad idea about histologic changes in tissues. Studies comparing the elasticity properties of normal and pathologic tissues are ongoing to further determine the diagnostic role of this technique. it can assess placental elasticity in normal pregnancies and pregnancies complicated by pre-eclampsia when performed during the second or third trimester as placental stiffness is affected by gestational age and severity of pre-eclampsia. This was based on the clinical observation of "poor" quality, smaller and stiffer placentas after delivery of preeclamptic patients as well as evidence of altered placental structure in pre-eclampsia **(27).**

As a new method for tissue characterization, it is useful for evaluation of placental function and can be used as a supplement to existing methods for prediction of pre-eclampsia **(28).**When preforming Shear Wave Elastography on placentas of pregnancies complicated by pre-eclampsia , it gives elastographic ranges and mean values that are significantly higher in all regions and layers than those In normal pregnancies with no placental anomalies or disorders in which placentation occurs by trophoblast invasion of the maternal spiral arteries to create a low resistance, high-flow maternal uteroplacental circulation , It is also observed that there is a significant difference between the elasticity values measured at the center and the periphery of the placenta between the two groups . The advantage of shear wave elastography is that it can be performed in the same session with the same device used for fetal anomaly scanning and Doppler imaging. The most important advantage of this non-invasive application is its operator independence. There is no need for dynamic compression, since shear wave elastography is based on acoustic radiation force impulses, However SWE limit examination to the anterior of fundal located placenta while posterior placenta is excluded from the study as it interfere with shear wave propagation **(29).**

Figure 20: *Shear wave elastography (SWE) images of placenta in pregnant women with and without pre-eclampsia. The sagittal imaging plane **(a)** shows the placenta of a 23-year-old pregnant woman in the 32nd week of gestation with no findings of pre-eclampsia. Two split US and shear wave elastography images are at the same level. The rectangular box represents the stiffness in blue and ROI is placed in the denser area. Mean and maximum elasticity was measured as 5.7 kPa and 9.8 kPa, respectively. Panel **(b)** shows the SWE image of a 30-year-old pre-eclampsia patient in the 28th week of gestation. The rectangular box represents the stiffness spectrum in blue to red. ROI is placed in peak stiffness area which is represented in red. Mean and maximum elasticity was measured as 56.2 kPa and 63.2 kPa, respectively* **(28) .**

REFERENCES

1. **Lee J , Kang H J , Yoon J H . et al ; (2021)** Ultrasound-guided transient elastography and two-dimensional shear wave elastography for assessment of liver fibrosis: emphasis on technical success and reliable measurements. Ultrasonography, 40(2), 217.
2. **Pedroso M A , Palmer K R , Hodges R J. et al ; (2018**) Uterine artery Doppler in screening for preeclampsia and fetal growth restriction. Revista brasileira de ginecologia e obstetricia, 40, 287-293.
3. **Oloyede O A , Iketubosin F. (2013)** Uterine artery Doppler study in second trimester of pregnancy. The Pan African medical journal, 15, 87.
4. **Nicolaides K , Rizzo G , Hecher K . et al ; (2005)** Doppler in obstetrics.
5. **Radswiki T , Weerakkody Y .(2022)** Umbilical arterial Doppler assessment. Reference article, Radiopaedia.org. (accessed on 22 Aug 2022).
6. **Maulik D , Mundy D , Heitmann E . et al ; (2010)** Evidence-based approach to umbilical artery Doppler fetal surveillance in high-risk pregnancies: an update. Clinical obstetrics and gynecology, 53(4), 869-878.
7. **Weerakkody Y , Yap J . (2022)** Fetal middle cerebral arterial Doppler assessment. Reference article, Radiopaedia.org. (accessed on 22 Aug

2022).

8. **Kachewar S G , Gandage S G A . (2012)** classification of patterns of fetal middle cerebral artery velocity waveforms as seen on Doppler ultrasound. Jpn J Radiol 30, 582–588 (2012).
9. **DeVore G R . (2015)** The importance of the cerebroplacental ratio in the evaluation of fetal well-being in SGA and AGA fetuses. American journal of obstetrics and gynecology, 213(1), 5-15.
10. **Weerakkody Y, Jones J .(2022)** Fetal ductus venosus flow assessment. Reference article, Radiopaedia.org. (accessed on 26 Aug 2022)
11. **Gournay V. (2011)** The ductus arteriosus: physiology, regulation, and functional and congenital anomalies. Archives of cardiovascular diseases, 104(11), 578-585.
12. **Seravalli V, Miller J L , Block-Abraham D . et al ; (2016)** Ductus venosus Doppler in the assessment of fetal cardiovascular health: an updated practical approach. Acta Obstetricia et Gynecologica Scandinavica, 95(6), 635-644.
13. **Larciprete G , Valensise H , Di Pierro G. et al ; (2005)** Intrauterine growth restriction and fetal body composition. Ultrasound in Obstetrics and Gynecology: The Official Journal of the International Society of Ultrasound in Obstetrics and Gynecology, 26(3), 258-262.
14. **Weerakkody Y.(2022)** Intrauterine growth restriction. Reference article,
15. **Radiopaedia.org. (**accessed on 26 Aug 2022)
16. **Fadl S A, Linnau K F, Dighe M K . (2019).** Placental abruption and hemorrhage—review of imaging appearance. Emergency Radiology, 26(1), 87-97.
17. **Suzuki R , Furuya N , Hasegawa J. et al ;(2022)** Ultrasonographic findings of placental abruption observed on superb microvascular imaging. Taiwanese Journal of Obstetrics and Gynecology, 61(4), 713-716.
18. **Ananth C V, Lavery J A , Vintzileos A M . et al ; (2016)** Severe placental abruption: clinical definition and associations with maternal complications. American journal of obstetrics and gynecology, 214(2), 272e1
19. **Shinde G R , VaSwani B P , Patange R P. et al ; (2016)** Diagnostic performance of ultrasonography for detection of abruption and its clinical correlation and maternal and foetal outcome. Journal of Clinical and Diagnostic Research: JCDR, 10(8), QC04.
20. **Ott J , Pecnik P , Promberger R . et al ; (2017)** Intra-versus retroplacental hematomas: a retrospective case-control study on pregnancy outcomes. BMC Pregnancy and Childbirth, 17(1), 1-8.
21. **Thapa S (2022).** Preplacental hematoma. Case study, Radiopaedia.org. (accessed on 26 Aug 2022)
22. **Miranda M L , Vallejo-Vaz A J , Cerrillo L .et al ;(2011)** The HELLP syndrome (hemolysis, elevated liver enzymes and low platelets): Clinical characteristics and maternal–fetal outcome in 172 patients. Pregnancy Hypertension: An International Journal of Women's Cardiovascular Health, 1(2), 164-169.
23. **Weerakkody Y. (2022)** HELLP syndrome. Reference article,
24. **Radiopaedia.org.** (accessed on 26 Aug 2022)
25. **Mould A , Abbott S , Welman C J. (2020)** HELLP syndrome: An ultrasound case of geographically altered liver parenchymal echogenicity with shear wave elastography, shear wave dispersion and attenuation imaging correlation. Australasian Journal of Ultrasound in Medicine, 23(2), 149-155.
26. **Nunes J O , Turner M A , Fulcher A S . (2005)** Abdominal imaging features of HELLP syndrome: a 10-year retrospective review. AJR. American journal of roentgenology, 185(5), 1205-1210.
27. **Chaiworapongsa T , Chaemsaithong P , Yeo L . et al ; (2014)** Preeclampsia part 1: current understanding of its pathophysiology. Nature Reviews Nephrology, 10(8), 466-480.
28. **Kılıç F, Kayadibi Y, Yüksel MA .et al ;(2015)** Shear wave elastography of placenta: in vivo quantitation of placental elasticity in preeclampsia. Diagnostic and Interventional Radiology, 21(3), 202.
29. **Cimsit C, Yoldemir T, Akpinar IN .(2015)** Shear wave elastography in placental dysfunction: comparison of elasticity values in normal and preeclamptic pregnancies in the second trimester. Journal of Ultrasound in Medicine, 34(1), 151-159.