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Research Paper

Anatomy of the placenta and related sonography

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Abstract
The placenta is a feto-maternal organ, an interface between the mother and the fetus. It supports the fetus in nutrition, respiration, and excretion. It is necessary for fetal development, safeguards the growing fetus, and supports the physiological changes in pregnancy. Although less evaluated during routine obstetric ultrasound scan, careful examination of the placenta can provide useful insights into clinically significant conditions that may affect feto-maternal welfare. Following a description of placenta development, the appearance of a typical placenta, placental grading which helps in predicting adverse fetal outcomes was discussed. A few pathological conditions affecting the placenta were discussed.

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I. Introduction

The placenta is a feto-maternal organ which was said to have derived its name from its appearance (*plakuos* in Greek, referring to "flat cake"). It performs nutritive and respiratory functions as well excretory roles in the fetus.[1]Its important role throughout pregnancy cannot be overemphasized as routine antenatal evaluation. Hence, an accurate systematic ultrasound assessment of the placenta is important.

This article described the development of the placenta, elaborating its normal anatomic featuresincluding its corresponding appearance on ultrasound. Furthermore, different pathologic conditions of the placenta including abnormal size, morphology, location, adherence, trophoblastic and non-trophoblastic tumours of the placenta are briefly highlighted.

Development of the placenta

At the outset of a typical gestation, the placenta and accompanying extra-embryonic membranes are derived from the zygote. The trophectoderm and the extraembryonic mesoderm beneath it are the two primary tissue origins of the placenta. With itsdifferentiation from trophectoderm, the trophoblastforms the placental epithelium and generates an invasive population of extra-villous trophoblast cells. The extraembryonic mesoderm differentiated from the trophoblast, develops into the stromal core of the placenta. Fibroblasts, acollection of blood vessels, and a host of resident macrophages develop from the stromal core of the placenta.[1]

The blastocyst cells differentiates into an embryoblast and a trophoblast, marking the beginning of the development of extra-embryonic membranes. The embryoblast develops later into embryo while the trophoblast develops into the embryonic appendage organs components. At about the 7th day following fertilization, the blastocyst becomes attached to the endometrial epithelium at its embryonic pole, the syncytiotrophoblast begin

to invade the connective tissue of the endometrium.[2] By the 9th day post fertilization, implantation of the blastocyst into the endometrium occurs. With the extensive syncytiotrophoblast formation at the embryonic pole, endometrial glands and the blood vessels become penetrated and invaded, setting up lacunar networks, forming the primordia of the intervillous spaces of the placenta. Acolumn of the stem cell for the formation of the villous becomes derived from the cytotrophoblast cells (Figure 1).[1, 3]

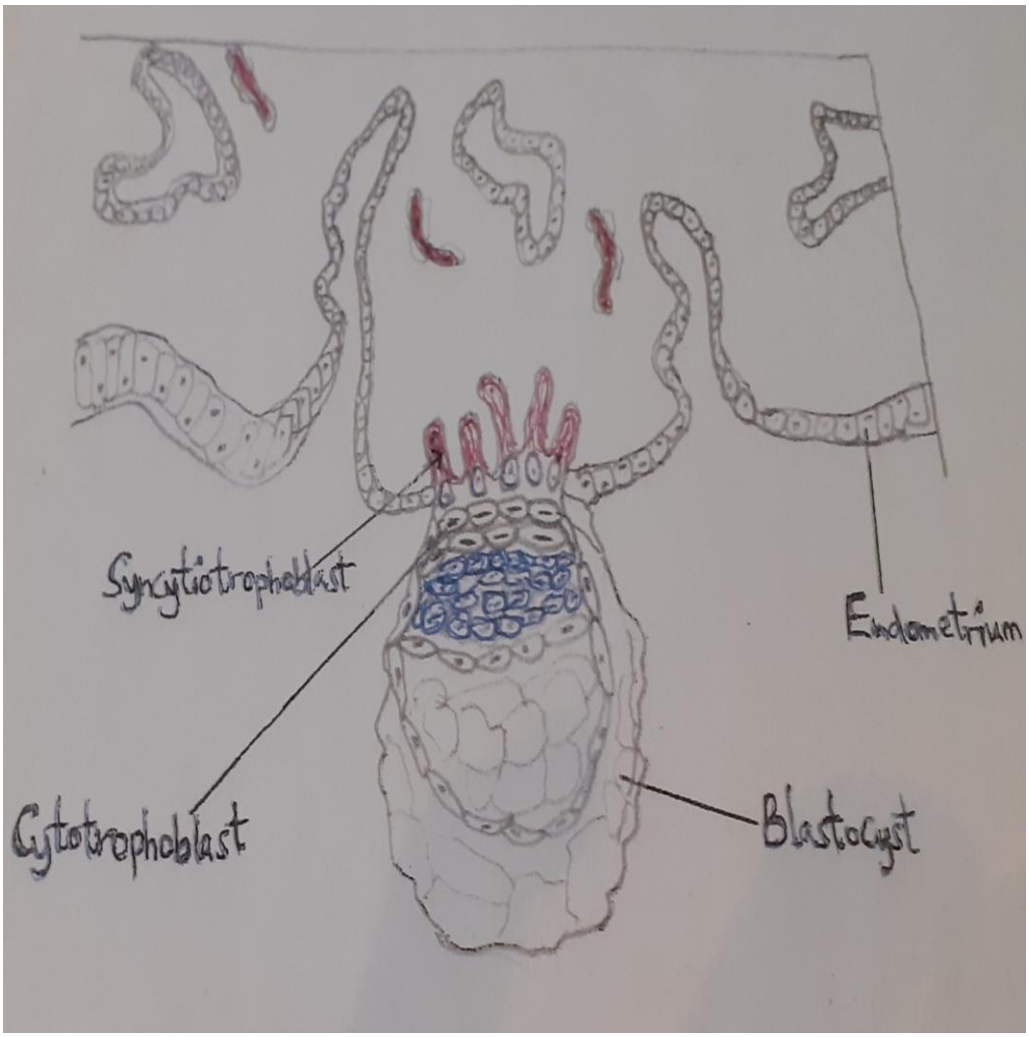


Figure 1: Schematic diagram showing formation of cytotrophoblast cells

By the 3rd week after fertilization (5th week of gestation) when feto-placental circulation begins, the placenta is connected with embryonic tissues by fetal vessels. With the development of the placental villi, the placenta adjusts itself to the needs of the developing fetus. The placenta is hemo-chorial, discoid, pseudo-cotyledonic, decidual or chorio-allantoid in humans.[1,2] As the chorionic sac enlarge, the decidua basalis-associated villi quickly proliferate, forming a brush-like area named the villous chorion (chorionfrondosum), evolving into the placenta.[1]After the 12th week of gestation, the intervillous blood flow is fully formed and a uteroplacental circulation withslow flow–low impedance becomes functional.[4]

The placental circulation system is made up of fetal and maternal components and the barrier created by the placenta separatesboth components. The placental barrier controls the exchange of metabolic processes between the embryo and the mother. Furthermore, the placenta is responsible for other important physiologic tasks (for instance, endocrine functions) while a normal pregnancy lasts.[5]

The development of fetal membranes is subject to several changes depending on whether the pregnancy is singleton or multiple. In multiple pregnancies, the fetal membrane development depends on certain changes which distinguish dizygotic twins from monozygotic ones.[3]The

umbilical cord which develops from the body stalk becomes covered by the epithelium of the amniotic cavity towards the end of the gestational period. The umbilical cord contains two umbilical arteries and one umbilical vein, with a surrounding connective tissue arising from the extraembryonic mesoblast. The umbilical cord of the embryo is situated in the amniotic cavity,and elongatesas the embryo develops progressively. The

amniotic fluid containing cavity performs metabolic functions between the mother andfetus.It also acts as a shock-absorber in pregnancy.[25]

Fetal pathologies such as fetal erythroblastosis, chorion carcinoma, hydatid mole are capable of affecting placental development. Similarly, toxemia of pregnancy and eclampsia are some of complications that may affect placental development. Other anomalies related to anomalous implantation position include ectopic pregnancy and placenta praevia. Marginal or eccentric insertion may also occur when the location of insertion of the umbilical cord at the placenta is abnormal.[2] All these anomalies results in abnormal fetal growth and development, abortion, or birth complications.

Anatomy of the normal placenta

The mature placenta is a roughly discoid in shape. It has a mean diameter of measuring 22 cm, thickness of 2.5 cm at the centre, and weight of about 0.5kg. The placenta comprises of parenchymal tissues,umbilical cord, and membranes.[6]

The umbilical cord measures about 0.8 cm to 2.0 cm in diameter. It is 30 cm to 100 cm long,and about 55 cm in mean. The umbilical cord has an umbilical vein, carrying oxygen-rich as well as nutrient-rich blood to the fetus. In addition, it also has two umbilical arteries transporting de-oxygenated blood away from it. A gelatinous substance called Wharton's jelly covers and protects the umbilical vessels. An estimated 35 ml/min of blood flow through the umbilical cord at 20 weeks of gestation while about 240 ml/min of blood flow through it at 40 weeks.[7]

The placental membrane consists of the amnion and the chorion (Figure 2). The amnion can be identified at about the 7^{th} or the 8^{th} day of thedevelopment of the embryo, engulfing the developing embryo.The placental parenchyma consists of a stromal compartment occupied by vascular and lymphatic channels. Eventually, the stroma becomesfairlyraised, having convex areas known as lobes with grooves partially separating them. The number of these lobes does not change throughout gestation ranging from as few as 10 to as many as 38.[3]

The surfaces of the placenta include the chorionic plate facing the fetus (and holding the umbilical cord attachment), and the basal plate abutting the maternal endometrium. The intervillous space, a cavity which lies between the chorionic and basal plates, receives the 30-40 deeply divided fetal villous sheet. Each villous tree arisesfrom a stem villus attached to the chorionic plate's deep surface and dividesagain and again to create a globe-like lobulewith a diameter of about 1 - 3 cm with a lobule's centre situated over the maternal spiral artery's openingvia the basal plate. Maternal blood let out at these openingsfilter through the villous branches before draining into the uterine veins' openings andleave the placenta. Each lobule thus depicts an independent exchange unit of materno-fetal circulation.[3]

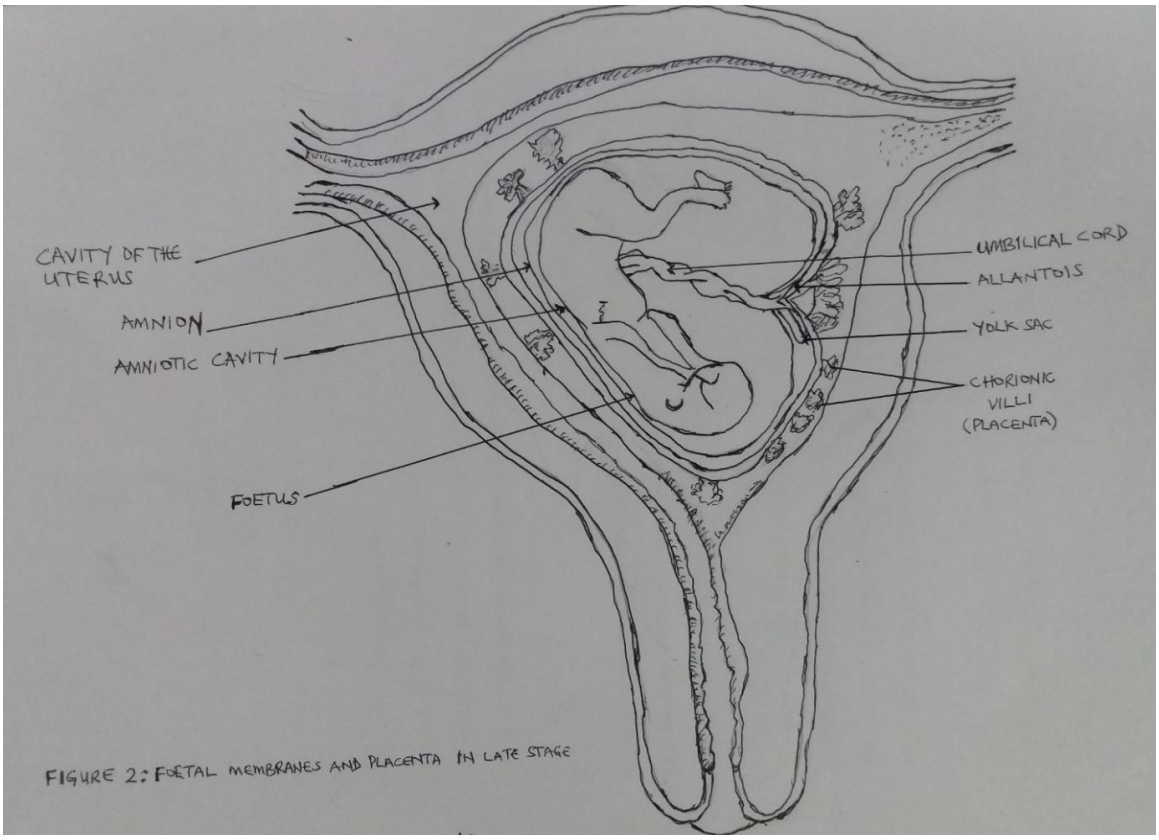


Figure 2: Schematic diagram showing fetal membranes and placenta in late stage

Ultrasound of the normal placenta

Ultrasound (US) is the initial imaging modality of choice for assessment of the placenta in most clinical conditions due to its safety in pregnancy, its availability, and the ready visibility of the placenta.[8]Fetal age can be calculated using the starting day of the last menstrual cycle, fertilization, or conception. As pregnancy progresses, the placenta grows larger and more echogenic.For instance, since conception happens roughly 14 days following the beginning day of the last menstrual cycle, six menstrual weeks are equivalent to four weeks of conception.

Transvaginal ultrasonography can detect a fluid-filled gestational sac with an echogenic rim approximately four weeks after the last menstrual period, when an intrauterine pregnancy may not yet be apparent. This illustrates the chorionic cavity and the chorionic villi that are implanting. In the early stages of the first trimester, the diameter of the gestational sac grows approximately 1 mm per day.

By the fifth week of pregnancy, a small mound of echogenic chorionic villi, a yolk sac, and an umbilical cord are visible. At this stage, true embryonic measurements can be taken for the first time. A normal yolk sac diameter ranges between 3 and 5 millimeters, and if it exceeds 6 millimeters, there is an increased risk of embryonic death.[9] By the end of the fifth week, the embryo should have grown from 2 to 3 mm to 3 to 4 mm in size. Although visualization of cardiac activity may be possible before the crown-rump length (CRL) can be measured, cardiac activity of the embryo should be visible when the CRL reaches 3 to 6 mm (approximately five to six menstrual weeks). By the end of the fifth week, the diameter of the gestational sac may increase from 16 to 23 mm. If a transvaginal ultrasound does not detect an embryo at 16 mm gestational sac size, an anembryonic pregnancy may be suspected.

In the first trimester, the placenta grows more quickly than the fetus. In a normal pregnancy, the placental weight increases during the second trimester, around 17 weeks gestation, and is proportional to the birth weight. At 37 weeks of gestation, the placenta thickness should not exceed 40 mm. Several maternal and fetal diseases have been associated with abnormally large placentas. In addition, polyhydramnios may be linked to an abnormally thin placenta.

The placenta may be seen as early as 6 weeks of pregnancy (4 weeks of fertilization) with transvaginal ultrasound and 10 weeks of pregnancy with transabdominal ultrasound, appearing as a thickened echogenic rim of tissue surrounding the gestational sac (Figure 3).[10] By the 12th to 13th week of pregnancy, the intervillous blood flow in the placenta can be demonstrated using Doppler US. Chorion and amnion fusion occurs between 12 and 16 weeks of pregnancy. In addition, by the 14th to 15th week of gestation, the placenta is well developed

and appears as a prominent hyperechoic area.[28] The retroplacental (subplacental) hypoechoic region is also referred to as the retroplacental clear space (Figure 4). The hypoechoic area composed of decidua, myometrium, and uterine vessels behind the placenta is known as the "retroplacental complex".

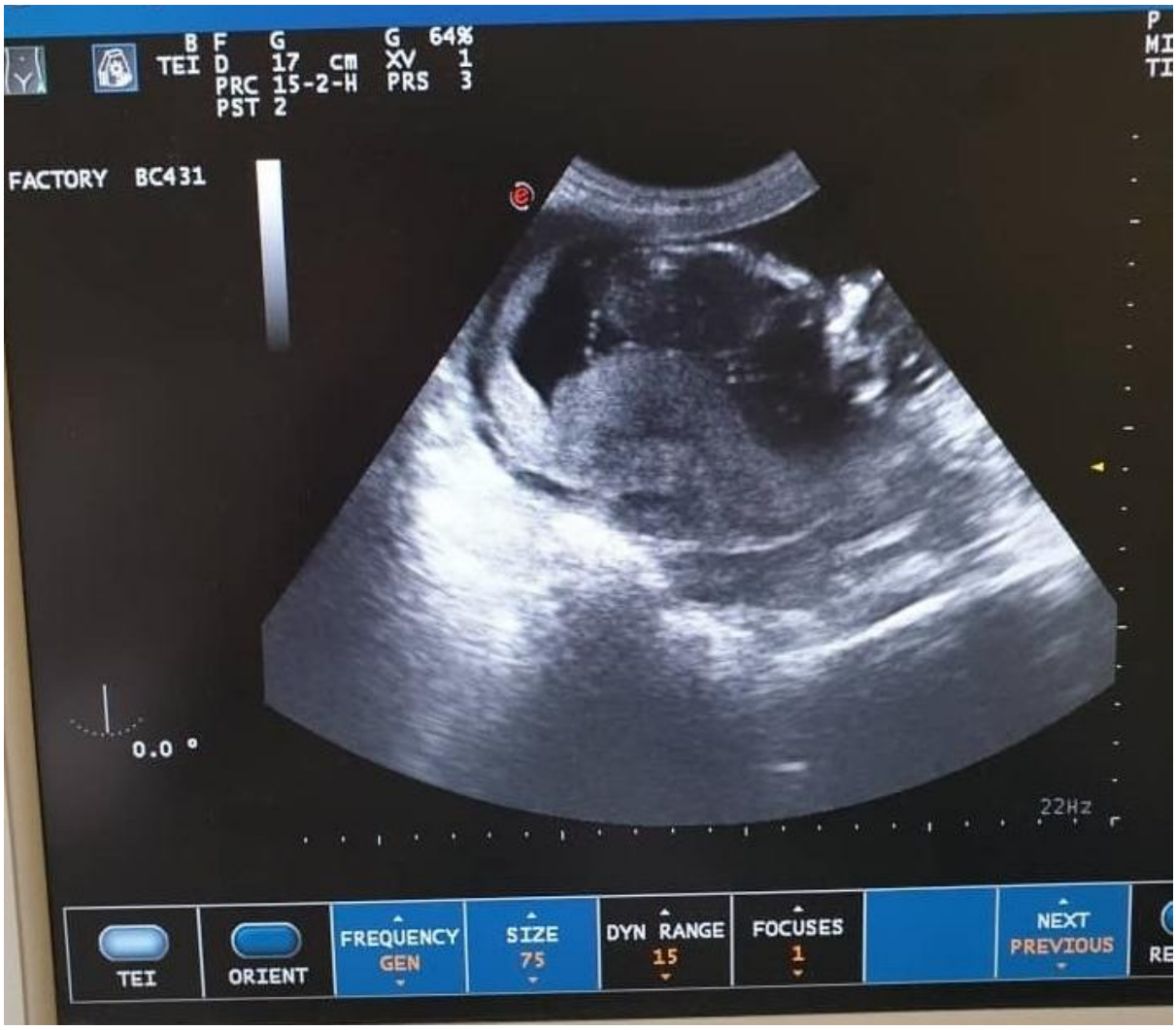


Figure 3: Transverse grey-scale US image of the normal placenta at 10 weeks gestation

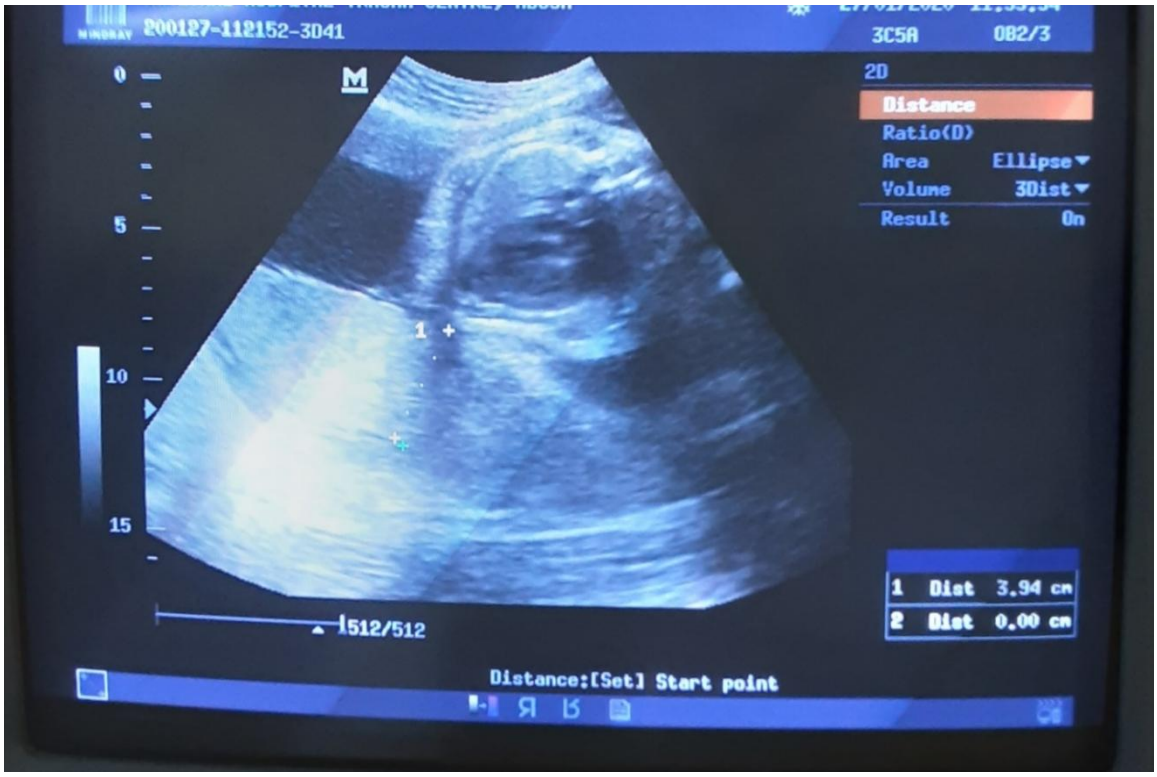


Figure 4: US image showing a placenta that is relatively homogeneous in echo-texture

Normal placenta during the second trimester has a rounded margin and a sheet-like edge. Ultrasound reveals a diameter of 15 to 20 centimetres and a thickness of 2 to 4 centimetres at this time (Figure 4).[11] It grows in thickness throughout pregnancy and progressively increases with gestational age. It is discoid with uniform echogenicity and rounded margins and extends to the lateral walls of the uterus from the anterior or posterior walls. It often shows a few focal sonographic lucencies with slow flow, called venous lakes. The chorionic plate is the fetal part of the placenta while basal plate is the maternal part of the placenta. Although there may be internal ill-defined hypoechoic areas representing placental lakes, the placenta appears more homogeneous and hyperechoic with increasing maturation and size in the second and third trimesters (Figures 5 & 6A). The insertion of umbilical cord is typically central. However, marginal and velamentous (within the chorioamniotic membranes) insertions also occur.

Throughout pregnancy, the thickness of the placenta increases proportionally to the gestational age. It extends from the anterior or posterior uterine walls to the lateral walls and has a discoid shape with uniform echogenicity and rounded margins. It frequently reveals a small number of focal sonographic lucencies with slow flow, known as venous lakes. The chorionic plate is the fetal component of the placenta, whereas the basal plate is the maternal component. In the second and third trimesters, the placenta becomes more homogeneous and hyperechoic as it matures and grows (Figures 5 & 6). Typically, the umbilical cord is inserted centrally. Nonetheless, marginal and velamentous (within the chorioamniotic membranes) insertions are also possible.

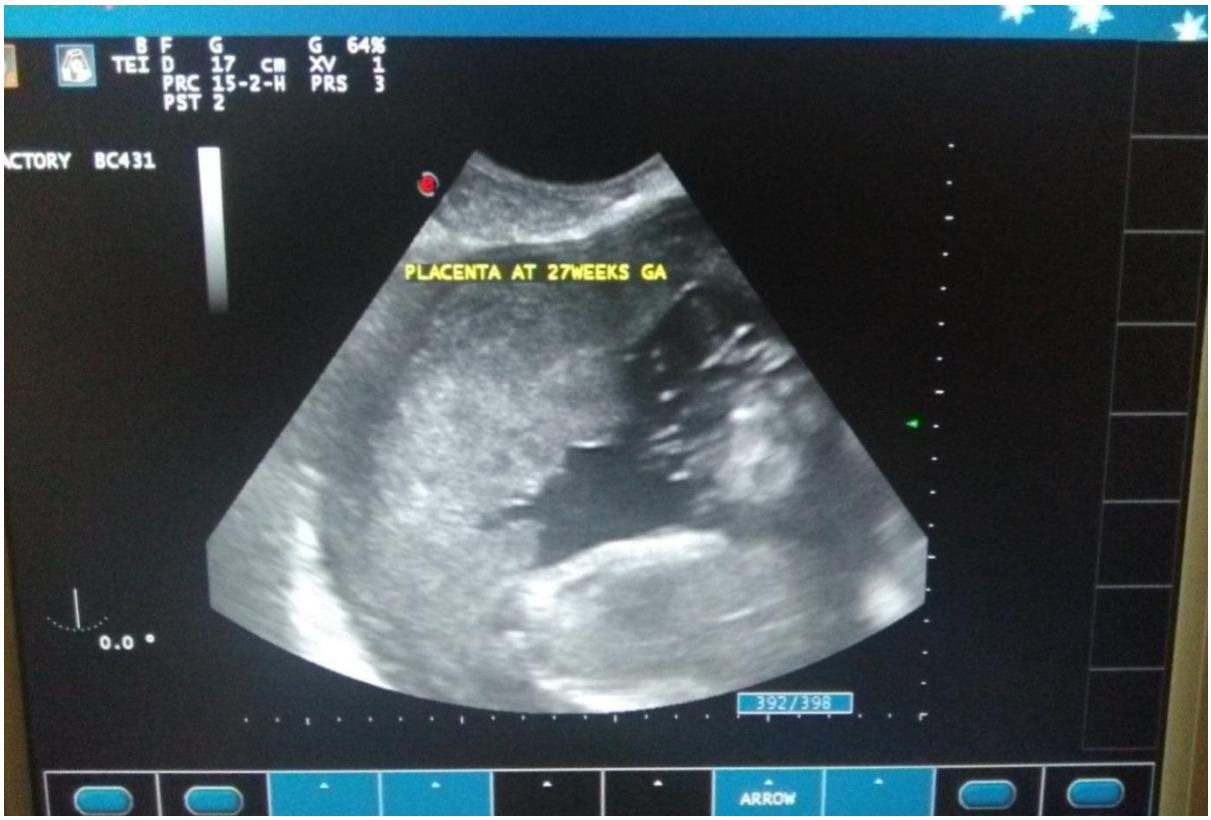


Figure 5: Ultrasound of the placenta at 27 weeks gestational age

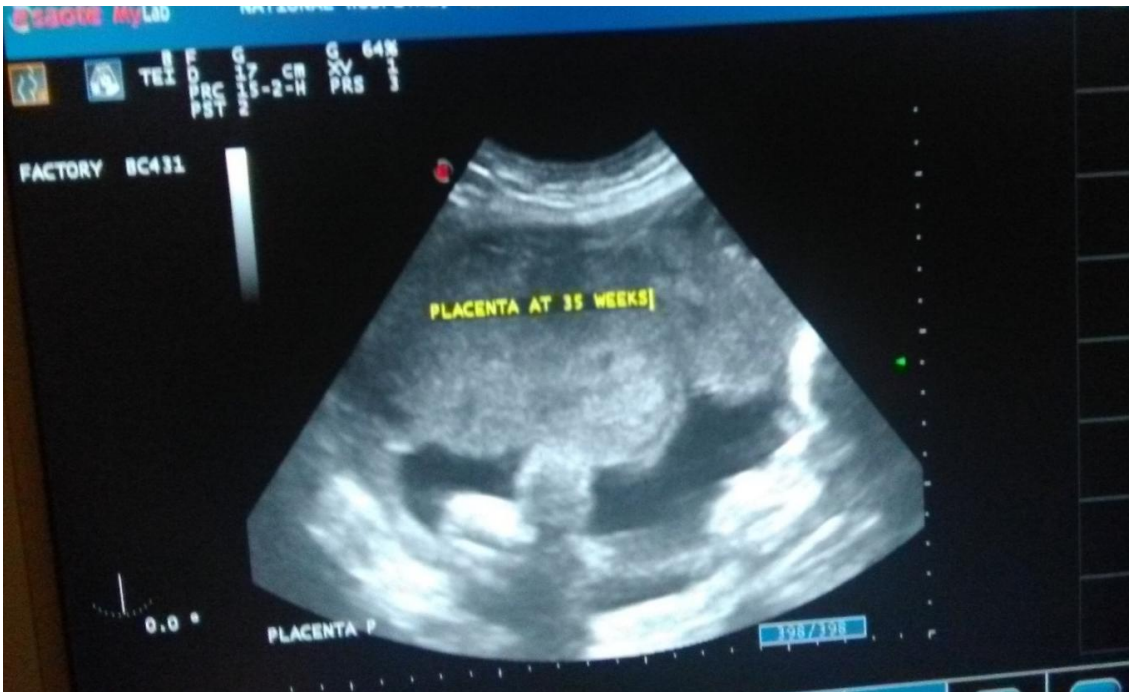


Figure 6: Ultrasound of the placenta at 35 weeks gestational age

Placental changes during pregnancy can be related to fetal maturity. The changes in maturation of the placenta occur in three main anatomic areas including the: i) Amnion chorion plate; ii) Placental body and; iii) Basal layers. As the placenta matures, calcifications develop. These features are often used in placental grading which helps in predicting adverse fetal outcomes. Ultrasound grading of the placenta is described as follows

Changes in the placenta during pregnancy may correlate with fetal maturation. Changes in the placenta's maturation occur in three major anatomical regions: the amnion chorion plate, the placental body, and the basal layers. The placenta develops calcifications as it matures. These characteristics are frequently

employed in placental grading, which aids in the prediction of adverse fetal outcomes. Placenta ultrasound grading is described as follows[12]:
Grade 0: Typically, during the first to early second trimester (10-17 weeks). No significant alterations to the placenta. There is uniform moderate echogenicity and a smooth, indentation-free chorionic plate.
Grade 1: This stage spans from the middle of the second trimester to the beginning of the third trimester (18-29 weeks). Subtle indentations of the chorionic plate are accompanied by small, diffuse calcifications in the placenta, constituting a significant change within the placental body.
Grade 2: This is late third trimester (30 weeks to delivery). This stage is characterized by two major placental changes. Basal calcification occurs in a linear fashion along the placenta-decidua junction. There are large indentations along the chorionic plate and "dot-and-dash" calcifications along the basilar plate.
Grade 3: This stage encompasses 39 weeks to post dates. The chorio-amniotic plates develop multiple depressions that extend to the base layer. There are complete indentations from the chorionic plate to the basilar plate, creating "cotyledons," as well as irregular calcifications with significant shadowing.

Abnormalities of the placenta: ultrasound findings
In terms of location and anatomy, the most common placental anomalies are placentas lying low in the uterine cavity close to the internal os, placenta previa, and abnormally invasive placentas.[13]

Low-lying placentas and placenta previa

When the placenta extends into the lower uterine segment and its edge lies too close to the internal os of the cervical canal without covering it, a low-lying placenta is present.[14, 15]Typically, this term is employed when the placental edge is between 0.5 and 5 cm from the internal cervical os.Some authors have used the term to define placental location when the placental edge is within 2 centimeters of the internal cervical os (Figures 7, 8. 12).[16]In contrast, placenta praevia refers to a placenta that abnormally covers the internal cervical os or lies abnormally close to it. It is a common reason for antepartum bleeding (Figures9-11).Praevia is subdivided into four grades based on its proximity and distance from the internal cervical os: i) Grade I: Low-lying placenta (Figure 8) - the placenta is located in the lower uterine segment in this case, but its lower edge is not in contact with the internal cervical os (i.e lower edge 0.5-2.0 cm from internal os); ii) Grade II: Placental tissue reaches the internal cervical os's margin, but does not cover it (Figure 9); iii) Grade III: Placenta partially covers the internal cervical os (Figure 10); and iv) Grade IV: Placenta completely covers the internal cervical os (Figure 11).Grades I and II are sometimes referred to as "minor" or "partial" placenta praevia, while grades III and IV are referred to as "major."[17]

A placenta praevia is typically not diagnosed until after 20 weeks of gestation due to placental trophotropism. During the "routine" 18- to 21-week morphology scan, measuring the distance between the internal os and the lower edge of the placenta is mandatory.If it is situated within a few centimeters of the internal cervical os, then a repeat ultrasound should be performed at approximately 32 weeks to confirm that the edge has moved further away.[18]

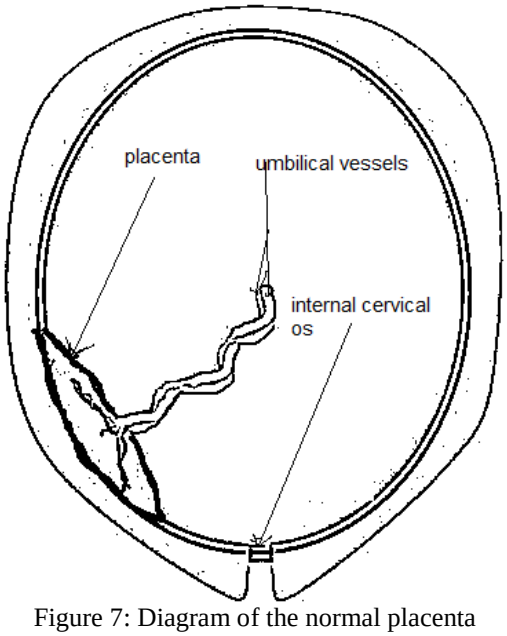


Figure 7: Diagram of the normal placenta

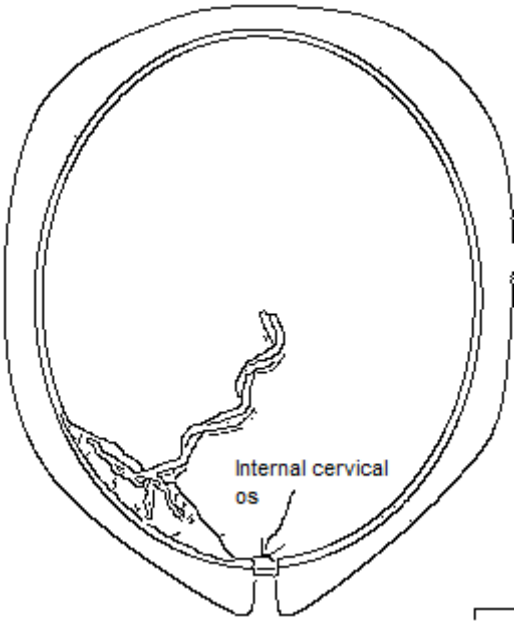


Figure 8: Diagram of the low-lying placenta

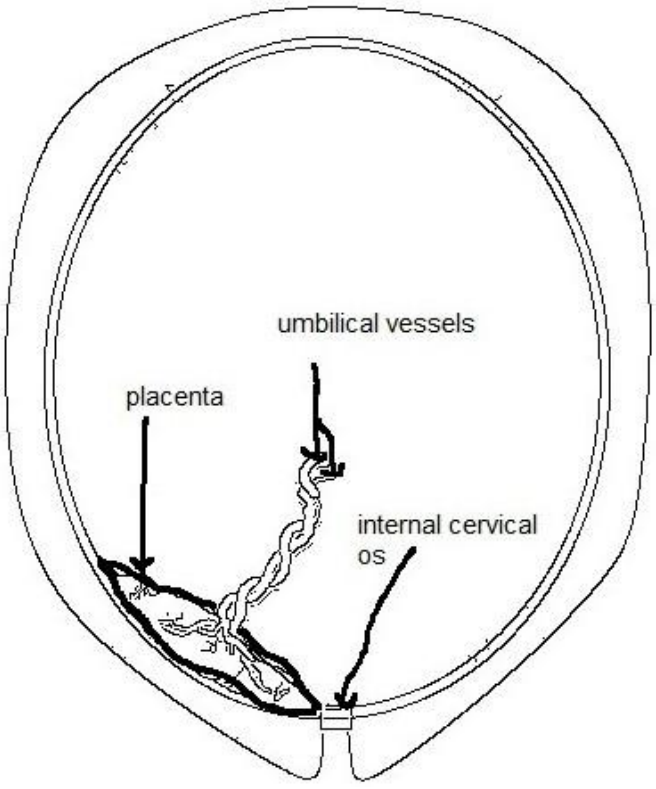


Figure 9: Diagram of a marginal placental previa

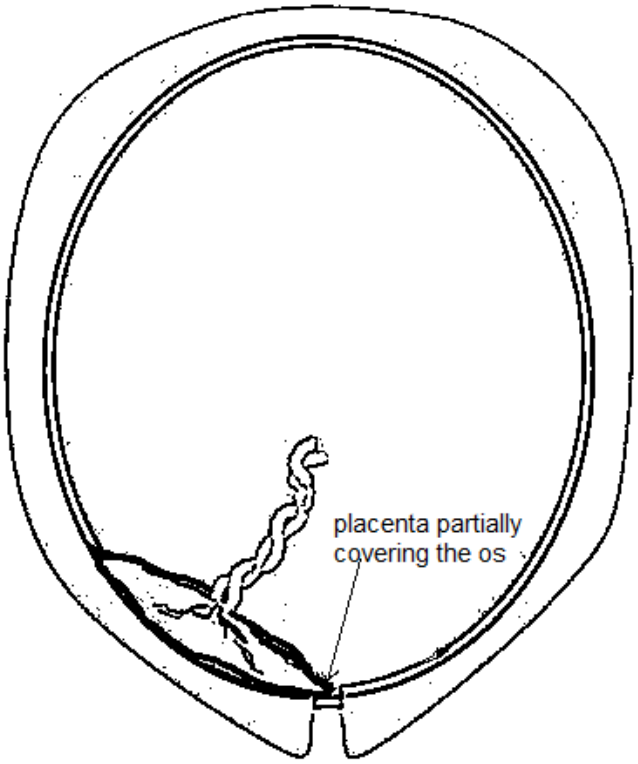


Figure 10: Diagram illustrating a partial placental previa

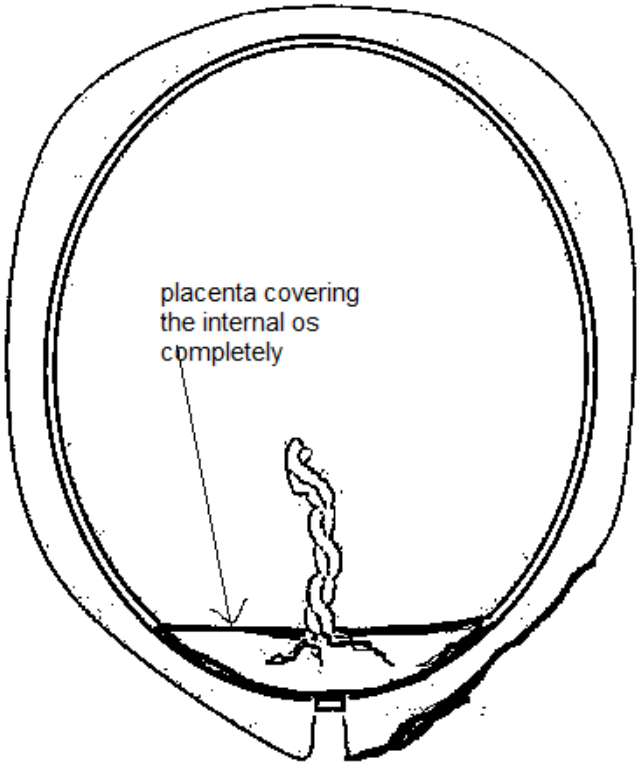


Figure 11:Diagram showing a complete placental previa

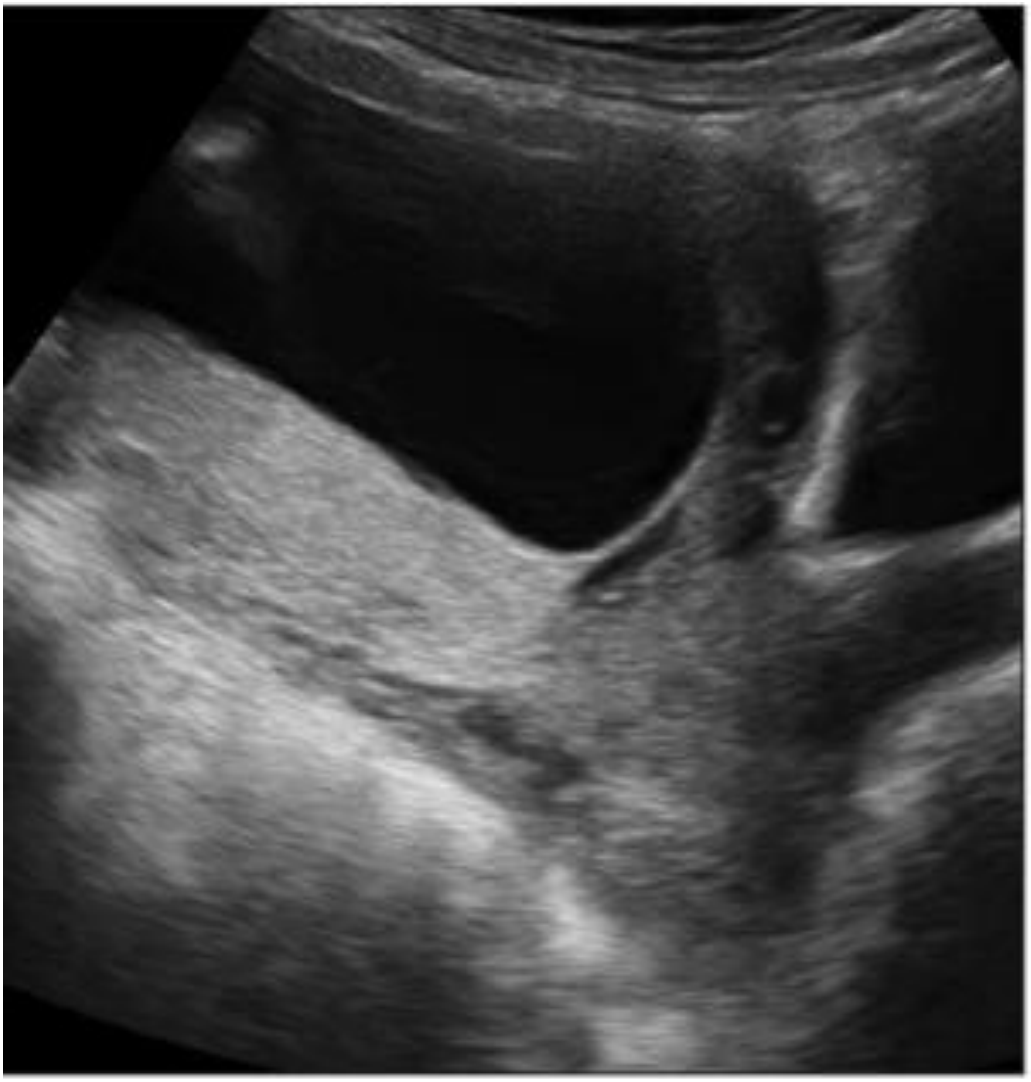


Figure 12: 17-week ultrasound image of a low-lying placenta

Source: Heller HT, Mullen KM, Gordon RW, Reiss RE, Benson CB. Outcomes of pregnancies with a low-lying placenta diagnosed on second-trimester sonography. J Ultrasound Med. 2014;33(4):691-6. doi:10.7863/ultra.33.4.691. *Reproduced with permission from John Wiley and Sons*)

Abnormally invasive placentas

One of the leading causes of antepartum hemorrhage is the abnormal placental invasion into uterine wall. During a typical pregnancy, a fibrinoid layer (Nitabuch's layer) separates the interface between the placenta and endometrium, preventing exceedingly deep implantation into the wall of the uterus. The Nitabuch allows for a normal third stage of labour by providing a cleavage plane. When this fibrin layer between the endometrial boundary and the cytotrophoblast shell of the placenta is compromised, an abnormally adherent placenta can develop.[19]

The term "morbidly adherent placenta (MAP)" refers to a range of pathologic extension of the placenta into the uterine wall. The level of the invasion into the wall of the uterusdefinesthe grading of abnormal placental attachment. Three conditions described in the pathologic placental invasion include: i) *Placenta accreta* - Placental chorionic villi attach to the myometrium after invading the desidua basalis; ii) *Placenta increta:* invasion of placental chorionic villi into myometrial wall; iii) *Placental percreta* - placental chorionic villi completely invade the myometrial wall, penetrating the serosa and invading surrounding structures (e.g. bladder and sigmoid colon).

Placenta accreta

Sonographic criteria for placenta accretadiagnosisinclude:i) Markedly thin or lost retroplacental hypoechoic zone; ii) Interrupted hyperechoic uterine-bladder border; a tissue echogenicity similar to that of the

placenta; iii) Presence of mass-like tissue with echogenicity similar to that of the placenta;and iv) Visualization of prominent vessels or lakes in the placenta or myometrium. Ultrasound detection of a placenta accreta on the posterior or lateral wall of the uterus may be difficult.[18, 19]

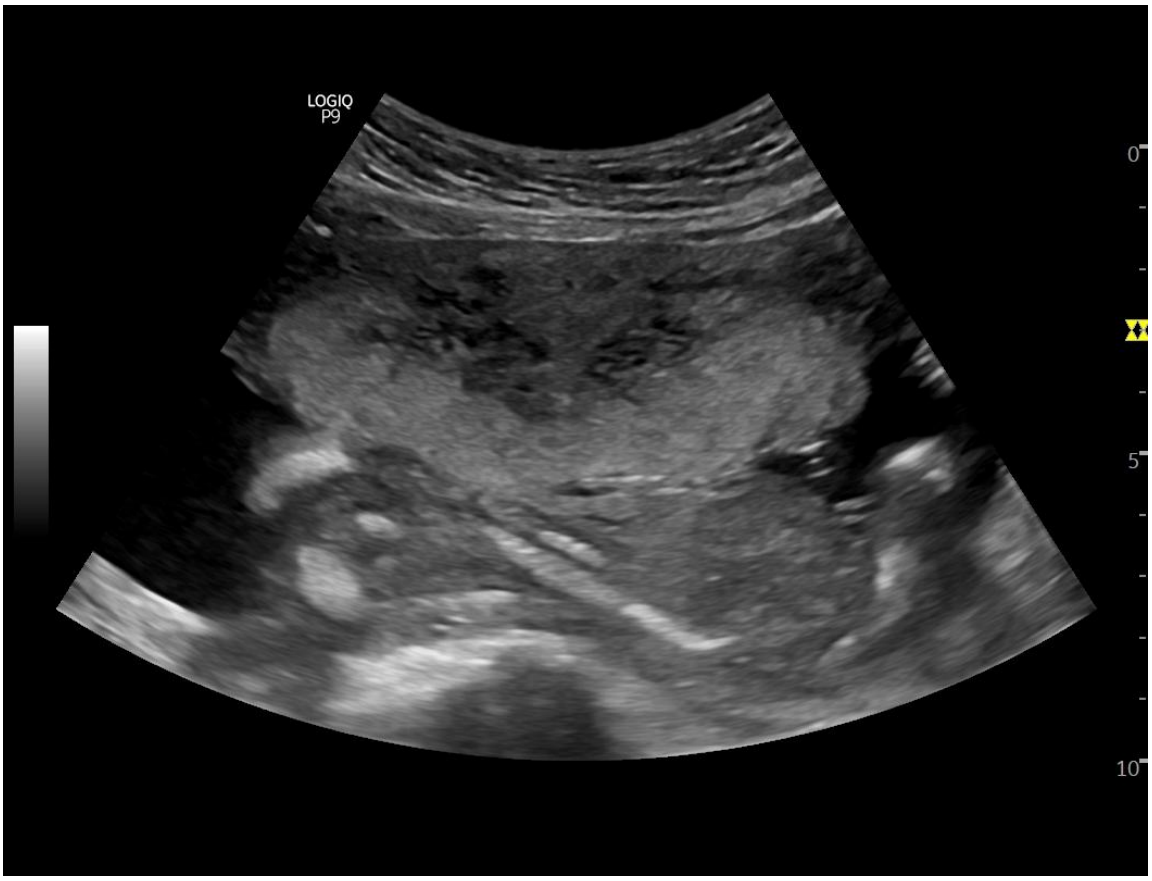
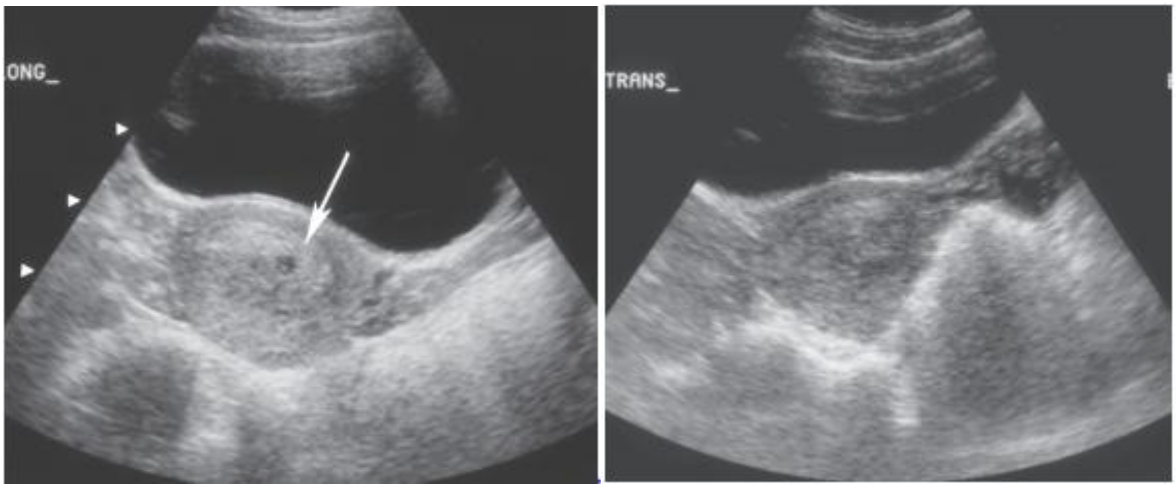


Figure 13: An ultrasound image of placenta accreta at 17.5 weeks of gestation.

Case courtesy of Dr Angel Romero Domínguez, Radiopaedia.org, rID: 98789.
Ultrasound reveals a healthy placenta and retroplacental-myometrial interface loss. The placenta has multiple tortuous hypoechoic structures ("Swiss cheese" appearance).

Placenta increta
Placenta increta accounts for 20% of abnormal placental villous implantation cases. The placenta invades the myometrium from the endometrium.Placenta accreta is one extreme of abnormal placental villi adherence. As with placenta accreta, retroplacental hypoechoic zone obliteration can occur.The spectrum of abnormal placental villi adherence includes placenta accreta and placenta percreta, with increta being in the middle.



A B

Figure 13 (A): Longitudinal ultrasound (transabdominal) image of the pelvis, showing ecogenic areas filling the cavity of the uterus. (B) Transverse ultrasound (transabdominal) image of the pelvis, showing maintained uterine contour and no evidence of extension into the abdomen.

Source: Avva R, Shah HR, Angtuaco TL. US case of the day. Placenta increta. Radiographics. 1999;19(4):1089-92. doi: 10.1148/radiographics.19.4.g99jl191089. PMID: 10464813. Reproduced with permission from RSNA)

Placenta percreta

Placenta percreta is the most severe and uncommon type of abnormal placental villous adhesion, characterized by a transmural extension of placental tissue across the myometrium and a serosal breach. It poses significant maternal and fetal risks. Ultrasound can detect the bulging of placental tissue beyond the uterine myometrium and an increase in vasculature between the serosa and adjacent structures, such as the bladder.

Other placental conditions

Other pathologic conditions affecting the placenta include placental hemorrhage or hypoxia showing increased placental echogenicity and preeclampsia is associated with decreased echogenicity and a jelly-like appearance of the placenta.[8]

II. Conclusion

The placenta is essential to the development of the fetus. The fetus is absolutely dependent on the placenta for survival; however, placenta-related pathologic conditions may have a direct impact on fetal morbidity and mortality. To rule out pathological conditions, it is necessary to perform a thorough evaluation of the placenta during routine prenatal ultrasounds. Radiologists and other professionals involved in antenatal care should be familiar with the various pathologic conditions of the placenta in order to expedite referral for appropriate maternal and fetal care.

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