

Ultrasonic Studies on Amniotic Fluid Umbilical Cord and Placenta

Kiyotake Ichizuka, Junichi Hasegawa, Ryu Matsuoka, Takashi Okai

Department of Obstetrics and Gynecology, Showa University, School of Medicine, Tokyo, Japan

Correspondence: Kiyotake Ichizuka, 1-5-8 Hatanodai Shinagawa-ku, Tokyo, Japan, Phone: +81-3-3784-8551, e-mail: ichizuka@med.showa-u.ac.jp

ABSTRACT

Detail evaluation of amniotic fluid, umbilical cord and placenta has been obtained by means of ultrasound new technology, including 3D color Doppler imaging. This paper summarizes fetal membrane anatomy and disorders using many ultrasound images taken by not only 2D gray scale ultrasound but also 3D color Doppler images.

Keywords: Amniotic fluid, Umbilical cord, Placenta, 3D Doppler.

AMNIOTIC FLUID

Amniotic fluid volume is an important parameter in the assessment of fetal well-being. There have been considerable two methods of amniotic fluid quantitative evaluation, amniotic fluid index (AFI)¹ and single deepest vertical pocket (SDP).²

Recently, some papers comparing the effectiveness between AFI and SDP reported that single deepest vertical pocket (SDP) measurement is more effective than AFI for evaluation of amniotic fluid volume as an indicator of the fetal well-being.^{3,4}

Amniotic Fluid Index (AFI)

Figure 1 shows a schema of AFI measurement. The patient is placed in the supine position. Using landmark on the maternal abdomen, the uterus is divided into four quadrants—right and left halves by the linear nigra, and the upper and lower halves by an imaginary line across the midway between the fundus of the uterus and symphysis pubis. The linear transducer head is placed on the abdomen along the mother's longitudinal axis and held perpendicular to the floor in the sagittal plane. The maximum vertical dimension of the largest fluid pocket in each quadrant are measured by millimeters. The measurements obtained from each quadrant were summed to form the amniotic fluid index (AFI). Ultrasound image of AFI are shown in Figure 2. The identified pocket is considered clear when umbilical cord and other small parts of the fetus are absent.

Single Deepest Vertical Pocket/Maximum Vertical Pocket (SDP/MVP)

Figure 3 shows the measurement of single deepest vertical pocket. According to the Cochrane database, the single deepest vertical pocket measurement in the assessment of amniotic fluid volume during fetal surveillance seems a better choice, because the use of the amniotic fluid index increases the rate of diagnosis of oligohydramnios and the rate of induction of labor without improvement in peripartum outcomes.

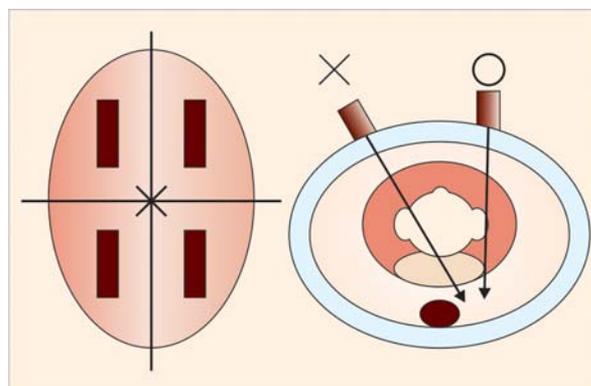


Fig. 1: Measurement of amniotic fluid index

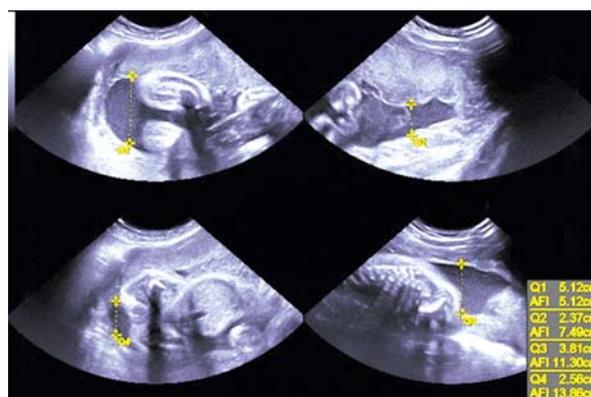


Fig. 2: Ultrasound image of AFI

Polyhydramnios

A single deepest vertical pocket of over 8 cm or AFI of over 24 cm is labeled as polyhydramnios. Figure 4 shows a case of polyhydramnios diagnosed by single deepest vertical method.

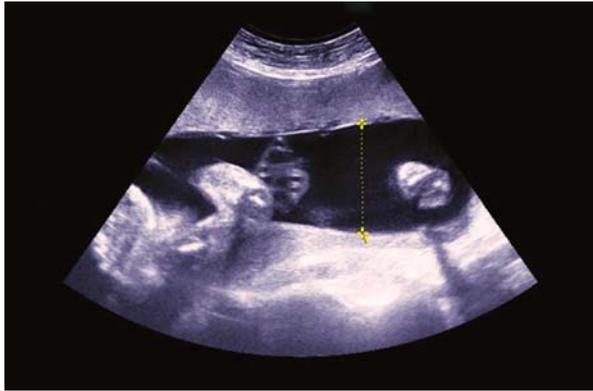


Fig. 3: Ultrasound image of single deepest vertical pocket



Fig. 6: Ultrasound image is free loop part of umbilical cord. Visualized by B-mode ultrasound



Fig. 4: Ultrasound image of polyhydramnios. Using single deepest method

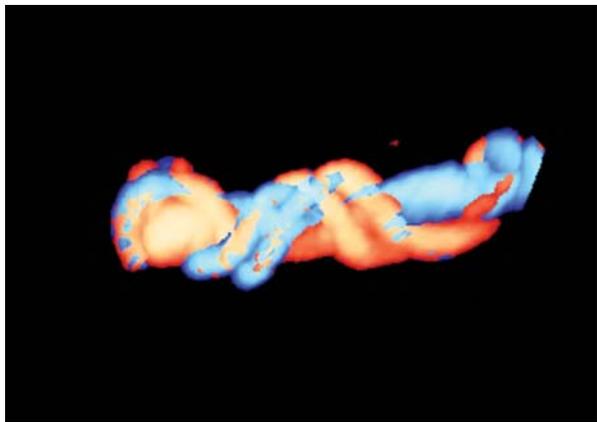


Fig. 7: Umbilical cord, visualized by 3D color Doppler ultrasound



Fig. 5: Ultrasound image of oligohydramnios. This case is donor fetus complicated by TTTS

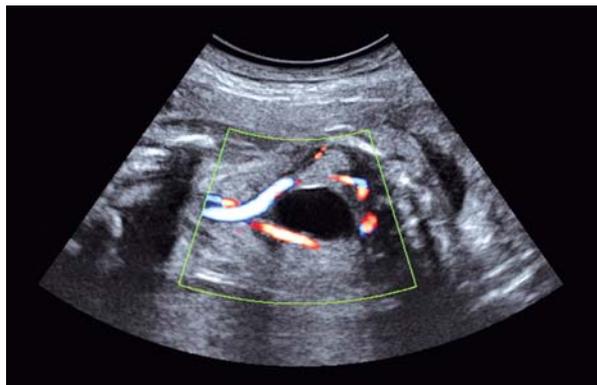


Fig. 8: Ultrasound image of intra-abdominal umbilical artery around the urinary bladder

Oligohydramnios

A single deepest vertical pocket of less than 2 cm or AFI of less than 5 cm is labeled as oligohydramnios. Figure 5 shows a case of oligohydramnios diagnosed by single deepest vertical method (A case of donor fetus in TTTS).

UMBILICAL CORD

Recently, the ability of ultrasound to evaluate the umbilical cord and number of vessels has dramatically improved. Figure 6 shows a picture of the normal three vessel umbilical cord taken

by B-mode gray scale ultrasound. Two arteries and one vein can be clearly seen. Figure 7 shows the normal umbilical cord visualized by 3D color Doppler imaging. Figure 8 shows the intra-abdominal umbilical artery. Normal paired umbilical arteries are confirmed adjacent to the urinary bladder with color Doppler imaging.

Evaluation of the Coiling of Umbilical Cord

Hyper- or hypocoiled cord has been reported to be associated with the higher prevalence of nonreassuring fetal status in labor

and small-for-gestational age (SGA) neonates⁵⁻⁷ (Fig. 9). So, it is important to evaluate the coiling of the umbilical cord during pregnancy. To evaluate the coiling of umbilical cord, usually umbilical coiling index (UCI) is used.⁸ The antenatal umbilical coiling index (UCI) is calculated as the reciprocal value of the distance between a pair of coils ($UCI = 1/\text{distance in cm}$). Abnormal cord coiling, i.e. $UCI < 10\text{th percentile} (< 0.07)$ or $> 90\text{th percentile} (> 0.30)$ is associated with adverse pregnancy outcome.⁹ An antenatal UCI below 0.2, which is called straight cord, and above 0.5 is called hypercoiled cord (Fig. 10). Figure 11 shows umbilical cord visualized by color Doppler imaging. Coiling index indicates 0.7. This umbilical cord is diagnosed by hypercoiled cord. Figure 12 shows the umbilical cord visualized by B-mode gray scale imaging. Coiling index indicates 0.1. This umbilical cord was diagnosed through hypo-coiled or straight cord. This imaging is the same straight cord visualized by 3D color Doppler (Fig. 13).

Cord Insertion (Placental Site)

The placental site cord insertion can also be visualized. Routine visualization of the placental insertion is essential in the diagnosis of marginal and velamentous insertion of the cord, and can also help us in the assessment of succenturiate placenta. Figure 14 shows the umbilical cord inserting into a center site of placenta. This image of cord insertion is visualized by B-mode gray scale imaging. We can recognize cord insertion using B-mode ultrasound. Figures 15 and 16 show the umbilical cord inserting into a center site of placenta too. These two images of the cord insertion are visualized by color Doppler and 3D color Doppler imaging respectively. The diagnosis of cord insertion has improved with the use of color/3D color Doppler imaging.

Velamentous Cord Insertion

Velamentous cord insertion (VCI) (Fig. 17) is an abnormal cord insertion in which the umbilical vessels diverge as they traverse between the amnion and chorion before reaching the placenta. Because, VCI is associated with fetal growth restriction, preterm labor, placental abruption, vasa previa, abnormal intrapartum fetal heart rate (FHR) patterns, low Apgar scores at 1 and 5 minutes and neonatal death, it has been proposed that detection of VCI should be included in the ultrasound examination during the second trimester.¹⁰ Figures 18A and B shows the ultrasound imaging of velamentous cord insertion visualized by color Doppler method. Upper picture shows the umbilical cord inserting into a velamentous site. Lower one shows umbilical vessels continuing in a submembranous location to the posterior placenta. Although, it is possible to recognize or diagnose the velamentous cord insertion using only B-mode ultrasound, usage of color Doppler makes it more easy to get the existing of aberrant vessels. The use of a color Doppler equipment is recommended.



Fig. 9: These umbilical cords are hypercoiled and straight cord respectively



Fig. 10: Coiling index = $1/\text{length of 1 cycle}$
0.5 <; hyper coiling, 0.2 >; hypo-coiled (straight) cord



Fig. 11: Hyper coiling cord visualized by color Doppler ultrasound image



Fig. 12: Ultrasound image of hypo-coiled cord

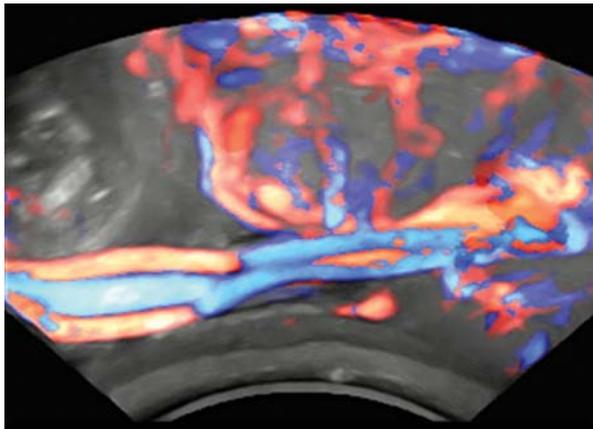


Fig. 13: Ultrasound image of hypocoiled cord visualized by 3D color Doppler ultrasound

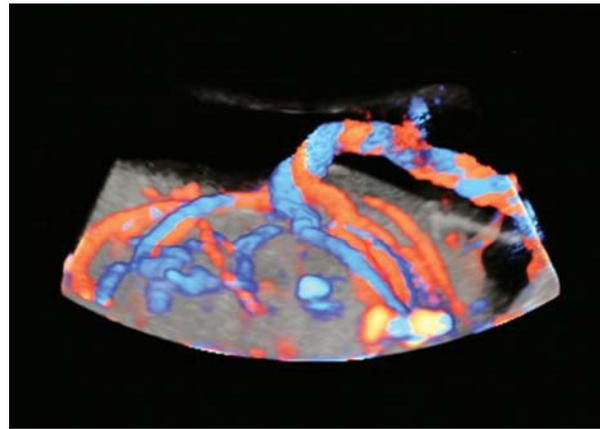


Fig. 16: Cord insertion into center site of placenta 3D color Doppler ultrasound



Fig. 14: Cord insertion into center site of placenta B-mode ultrasound

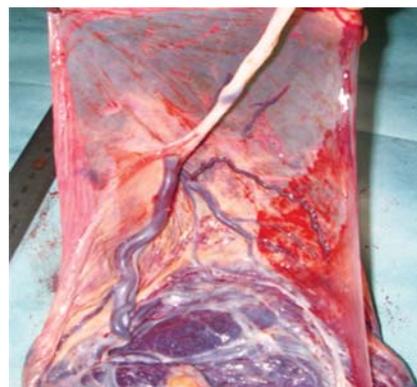


Fig. 17: Picture of velamentous cord insertion



Fig. 15: Cord insertion into center site of placenta color Doppler ultrasound

Nuchal Cord (Cord Around the Neck)

It is well-known that the umbilical cord can become coiled around the fetal body parts, especially around the neck. According to the previous reports, an incidence of nuchal cord ranged from 15.8 to 31%.¹¹ Many retrospective studies conclude

that single entanglement of the nuchal cord is not associated with significant neonatal morbidity or mortality.^{12,13} The presence of a nuchal cord is able to be suspected by ultrasound using B-mode gray scale. The ultrasound transducer was placed parallel to the longitudinal axis of the fetal neck, and the presence of nuchal cords are visualized as dimples (Fig. 19A). Number of dimples related to the number of cord entanglements. Doppler ultrasound image showing the fetus in the longitudinal position, face down; three times nuchal cord loops are wrapped around its neck (Fig. 19B).

Discent of the Cord

Figure 20 shows the case of descent of the cord visualized by transvaginal ultrasound. Diagnosis is very easy and simple. But diagnosis before start of labor will provide us with valuable information.

Single Umbilical Artery (SUA)

Single umbilical artery (SUA) is by far the most common anomaly of the umbilical cord seen in new born infants. In the



Fig. 18A: Ultrasound image of velamentous cord insertion

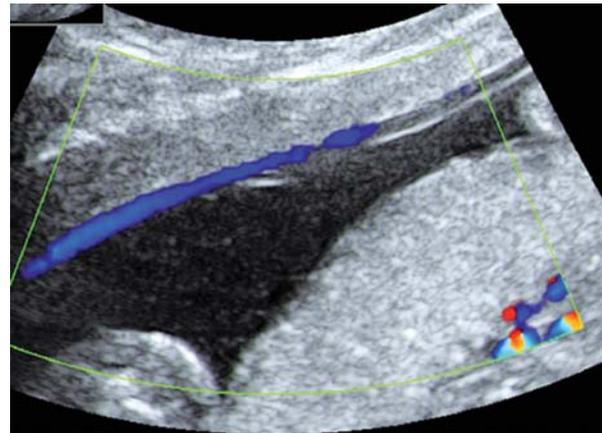


Fig. 18B: Case of velamentous cord insertion. Afferent vessel is visualized by color Doppler ultrasound



Fig. 19A: Nuchal cords are visualized as adimples by B-mode ultrasound



Fig. 19B: Nuchal cords (3 times) visualized by color Doppler ultrasound



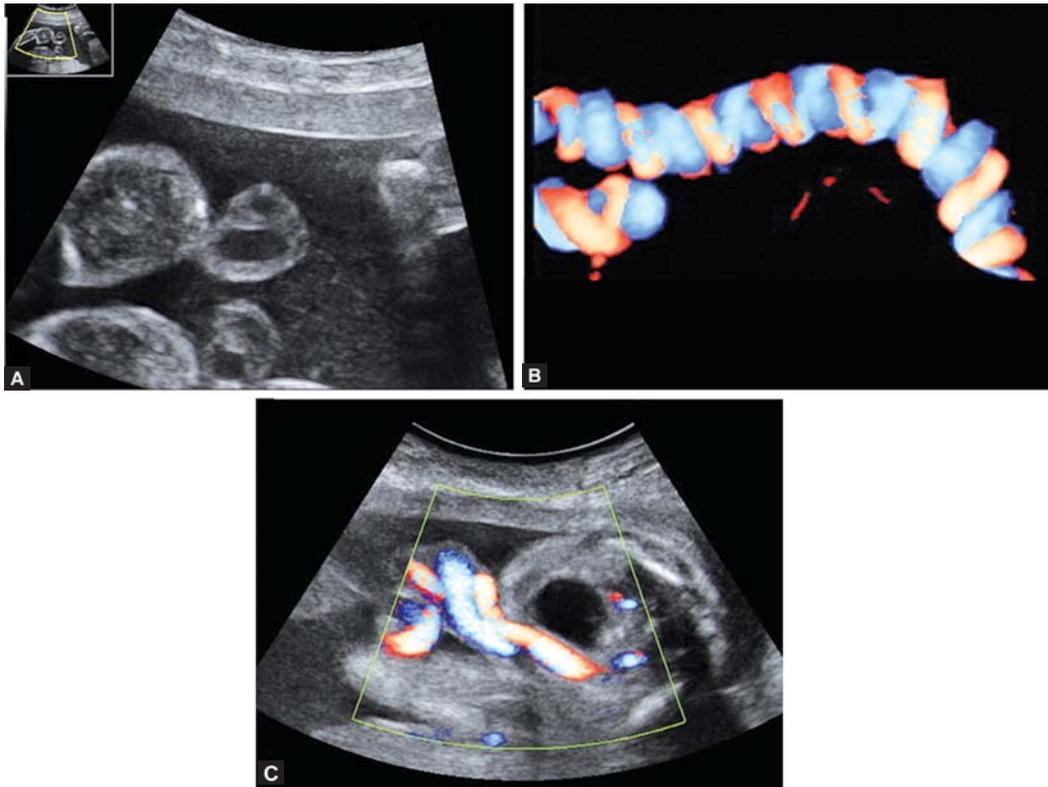
Fig. 20: Case of descent of the cord

previous report, the prevalence of SUA is about 1%.¹⁴ Caucasians have the higher frequency of SUA than blacks and Japanese. SUA has been increasingly recognized in the second and third trimesters as the result of routine assessment of the

fetal screening echo. The basic screening technique is to identify the two vessels of transverse view of a free loop of the cord with adequate magnification. Larger vessel is the vein and the smaller is the artery. Figure 21A shows B-mode cross-section of SUA. Figure 21B shows color 3D Doppler imaging of a two vessel umbilical cord, representing a single umbilical artery and vein. Figure 21C shows color Doppler imaging which confirms a SUA coursing around the urinary bladder.

PLACENTA

Figure 22 is a schematic drawing of placental circulation during the third trimester. Maternal blood supplied by the spiral arteries circulates in the intervillous space, bathes the placental villi, and then egresses through periplacental veins. Fetal blood from the umbilical artery supplies the villi and returns via the umbilical vein. The blood flow from spiral artery to the intervillous space is drawn. This blood flow is like a geyser. The placenta consists of about 30 cotyledons. There are about three spiral arteries under each cotyledon. Therefore, there are about 100 spiral arteries with one placenta. Figure 23A shows



Figs 21A to C: Single umbilical artery: (A) B-mode ultrasound, (B) 3D color Doppler ultrasound, (C) Confirmed by visualization of intra-abdominal umbilical artery

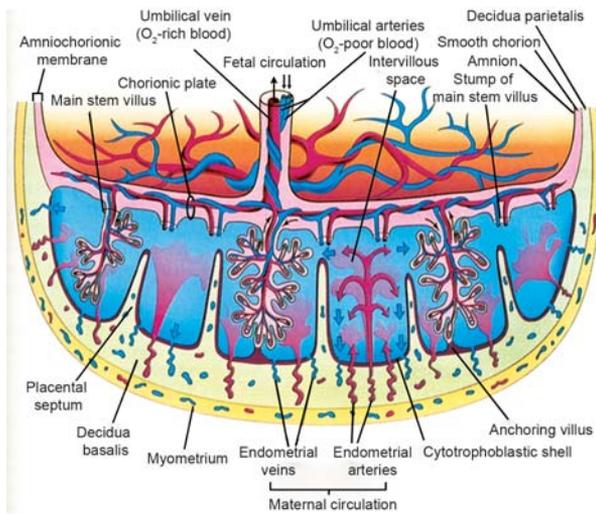


Fig. 22: A schematic drawing of placental circulation (Courtesy by Moore KL)

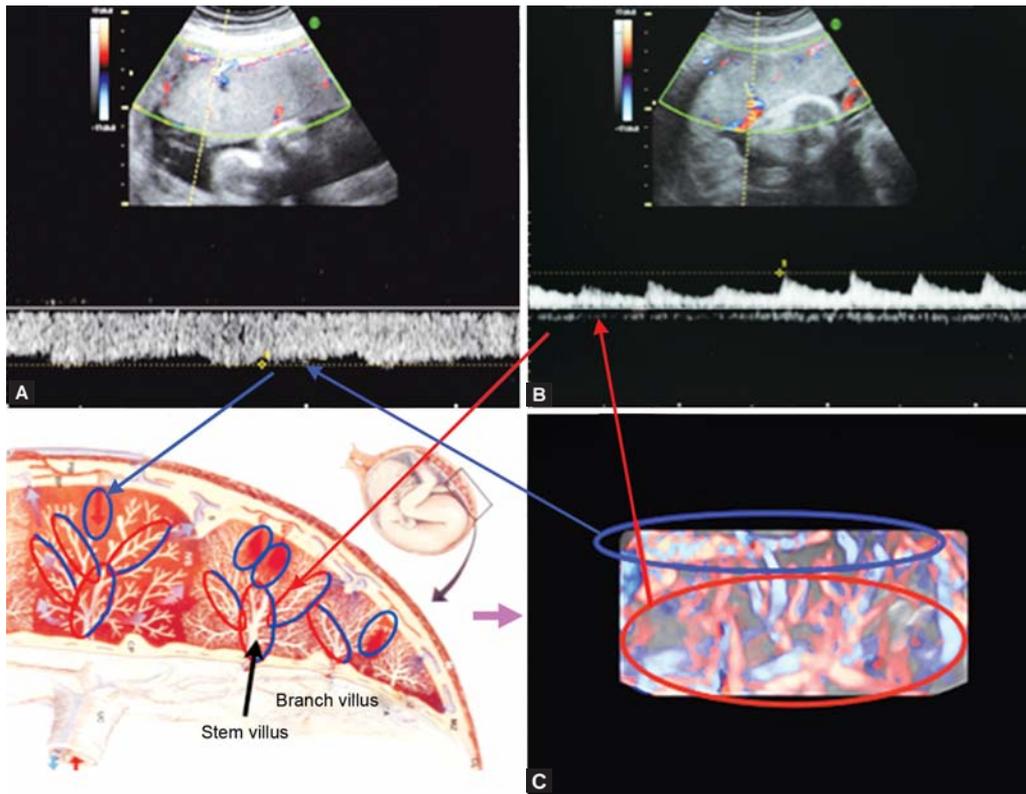
the O₂ rich blood flow from mother to fetus. Pulse rate synchronize the mothers one. Figure 23B shows the O₂ poor blood flow from fetus to mother. Pulse rate synchronizes the fetus. Figure 23C shows intraplacental vessels that are visualized by 3D color Doppler imaging. These vessels represent stem villi and blood flows of intervillous space.

Placenta Previa

Before making diagnosis of placenta previa, we have to understand the change of the cervix during pregnancy. The left side schema (Fig. 24) is the uterine body, including placenta and cervix before 20 weeks of gestation, where the isthmus still exists. Placental edge is in contact with the uterine anatomical internal os. It seems like a marginal placenta previa, though it is not correct. The right side schema (Fig. 24) is the uterus after 20 weeks of gestation. In this stage, the isthmus becomes lower segment, and placental edge is already away from the histological internal uterine os. Therefore, when we diagnose placenta previa, we need to distinguish histological os from anatomical os using ultrasound. Figure 25 shows a placenta previa totalis. The placenta covers the histological internal os completely. Figure 26 shows a partial placenta previa. Japan Society of Obstetrics and Gynecology (JSOG) sets a definite difference among marginal, partial and total placenta previa. When the shortest distance between histological os and placental edge is over 2 cm, it is diagnosed as total placenta previa, and when it is less than 2 cm, the diagnosis is partial placenta previa. Marginal placenta previa, defined as distance from histological internal os to placental edge, is 0 cm.

Abruptio Placenta

The sonographic findings of placental abruption vary greatly with age of onset of hemorrhage. Acute hemorrhage is



Figs 23A to C: (A) Blood flow from mother to fetus, (B) Blood flow from fetus to intravillous space (C) Intraplacental vessels visualized by 3D color Doppler ultrasound

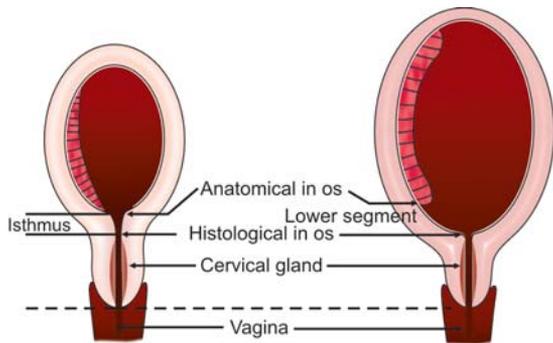


Fig. 24: Change of the cervix during pregnancy



Fig. 26: A case of partial placenta previa visualized by TV ultrasound



Fig. 25: A case of placenta previa totalis visualized by TV ultrasound



Fig. 27: A case of acute phase placental abruption



Fig. 28: A case of chronic phase placental abruption

hyperechoic and may be difficult to distinguish from the placenta in some cases. So, acute phase hemorrhage may be seen as an thickened placenta.¹⁵ Figure 27 shows a placental abruption 2 hours later from onset of clinical symptom. Resolving hemorrhage becomes hypoechoic and then sonolucent within 1 to 2 weeks. Figure 28 indicates a case of chronic phase of placental abruption (30 weeks of gestation). Around 1 week after initial clinical symptom, premature uterine contraction and small vaginal bleeding, the hematoma has become nearly sonolucent in appearance.

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