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The Role of Obstetric Ultrasound in Reducing Maternal and Perinatal Mortality

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1. Introduction

The joy that every expectant couple, family, or community has when a woman gets pregnant is suddenly turned into sorrow and mourning when the woman dies during pregnancy or child birth, or when the baby dies. According to the World Health Organization (WHO), the five major causes of maternal mortality are hemorrhage, sepsis, complications of abortion, eclampsia, and obstructed labour (Bale et al, 2003).

The WHO similarly lists the most common causes of neonatal mortality as infections, birth asphyxia, birth injuries, preterm births, and birth defects (Bale et al., 2003). It is worth noting that these mortality causes are conditions for which timely ultrasound imaging could be of immense help in early diagnosis and hence intervention, leading to the reduction of mortality rates among mothers and their babies.

It is also notable that most of these avoidable deaths (99%) occur in developing countries, where ultrasound imaging is currently underutilized, and financial constraints have been cited as the main reason. However, the usefulness of ultrasound imaging in preventing these needless deaths has not been fully exploited. It is anticipated that low resource settings could benefit by prudent application of this modern technology which is a relatively affordable and safe imaging modality. In recent times technology has made this modality so affordable and widely available, that it is unacceptable to watch such needless deaths occur when ultrasound application could help improve survival rates.

This chapter discusses the usefulness of ultrasound imaging at various stages of pregnancy, whether in apparently normal or high risk situations. Current advances in obstetric ultrasound application and imaging techniques that are helpful for improving pregnancy outcome are discussed. The chapter also addresses the availability of more affordable but high quality ultrasound equipment that can improve obstetric healthcare, accentuating the need to implement sustainable ultrasound practice standards in developing countries where the current rate of maternal and perinatal mortalities is unacceptably high.

It must be emphasised that the objective and focus of this chapter is the role ultrasound plays in the diagnosis and in some cases follow-up or interventionary guidance, not the management of the various conditions. Readers may consult other literature for the specific management of these conditions.

2. Reducing mortality rates by ultrasound imaging in the first trimester

Ectopic pregnancy, abortion, and gestational trophoblastic diseases (GTDs) are the commonest conditions of the first-trimester that can cause maternal mortality, due to the

possibility of severe haemorrhage, shock or sepsis. Patients usually present with bleeding and/or pain but can also remain asymptomatic for a long time. In some cases patients don't even realize that they are pregnant, particularly in some cases of ectopic pregnancy and missed abortion. Ultrasound imaging is extremely useful for obtaining accurate diagnosis for these first trimester conditions. It is therefore important to exclude early pregnancy pathology in every woman of reproductive age who presents with amenorrhoea, abnormal bleeding and/or pain, using diagnostic ultrasound imaging in combination with beta human chorionic gonadotropin (β -HCG). This approach to medical care can potentially reduce maternal mortality rates.

In terms of perinatal mortality the role of ultrasound imaging in detecting markers for chromosomal anomalies and structural defects in the fetus to enable early intervention or close monitoring is very important.

2.1.1 Ectopic pregnancy

Ectopic pregnancy accounts for 9% of all pregnancy-related deaths (Uzelac and Garmel, 2007). However, because of improved diagnostic capabilities, notably in ultrasound imaging, the incidence of mortality has relatively declined in the US and other developed countries since the 1970s, despite the increasing number of ectopic pregnancies (Lawson et al, 1988; Levine, 2000). This implies that improving on the use of ultrasound imaging in developing countries could equally improve survival rates of deaths caused by ectopic gestation.

In the evaluation of suspected ectopic pregnancy β -HCG and ultrasound complement each other. Transvaginal sonography (TVS) is able to reliably identify an intrauterine gestational sac when the serum β -HCG is 1000mIU/ml and transabdominal sonography (TAS) when the β -HCG level is 1800-3600mIU/ml. Thus TVS detects either a normal or an abnormal intrauterine gestational sac earlier than TAS. With TVS the transducer is closer to the uterus and adnexae allowing higher frequencies to be used, since there are fewer tissue interfaces with less beam scatter and the effect of abdominal wall fat is avoided, (details of the TVS technique are described in another section of this chapter).

In sonographic diagnosis of ectopic pregnancy, TVS may reveal only a thickened decidualised endometrium. With more advanced ectopic pregnancies, decidual sloughing with resultant fluid or blood in the cavity may lead to the formation of a small and irregular intrauterine structure, the so-called pseudogestational sac. Diagnostic accuracy is further enhanced by the use of transvaginal colour Doppler sonography (TV-CDS) compared with the use of TVS alone, which will detect an increased peritrophoblastic flow on colour Doppler at the site of implantation.

In a patient with a positive β -HCG who has no sonographic evidence of an intrauterine pregnancy, the presence of an adnexal mass is suggestive of ectopic pregnancy with a positive predictive value of 70% to 75% (Nyberg et al, 1991).

In some cases, an echogenic adnexal ring will be seen separate from the ovary, known as tubal ring. Tubal ring has been detected in 68% of unruptured tubal pregnancies using TVS, with a positive predictive value of 100% (Fleischer et al, 1990; Nyberg et al, 1991)

The specific diagnosis of ectopic pregnancy however, is the demonstration of a gestational sac with an embryo in the adnexa (Nyberg et al, 1991) (Figure 1). A live extrauterine fetus can be detected with TVS in 17% to 28% of patients with ectopic pregnancies (Thorsen et al, 1990; Fleischer et al, 1990) compared with approximately 10% with TAS (Mahony et al, 1985), implying that an examiner should progress to TVS if TAS findings are suboptimal.

With TV-CDS an adnexal peritrophoblastic flow with a high-velocity and low-resistance spectral pattern may be demonstrated, separate from the ovary (Pellerito et al, 1992).

Also the presence of free fluid in the pouch of Douglas is a nonspecific finding that suggests the presence of an ectopic pregnancy in the appropriate clinical setting. The amount of fluid and the echogenicity of the fluid are important clues in predicting the presence of a ruptured ectopic pregnancy. Large amounts of fluid and increased echogenicity of the fluid are both more indicative of a ruptured ectopic pregnancy (Frates et al, 1994). In patients with suspected ectopic pregnancy, the combination of an adnexal mass and echogenic free fluid is associated with a 97% positive predictive value for ruptured ectopic pregnancy (Nyberg et al, 1991). Detecting the ectopic pregnancy before rupture will avoid blood loss and consequent morbidity and mortality (Dassah et al, 2009). Even when rupture has occurred early detection by ultrasound imaging will obviously help to prevent further blood loss.

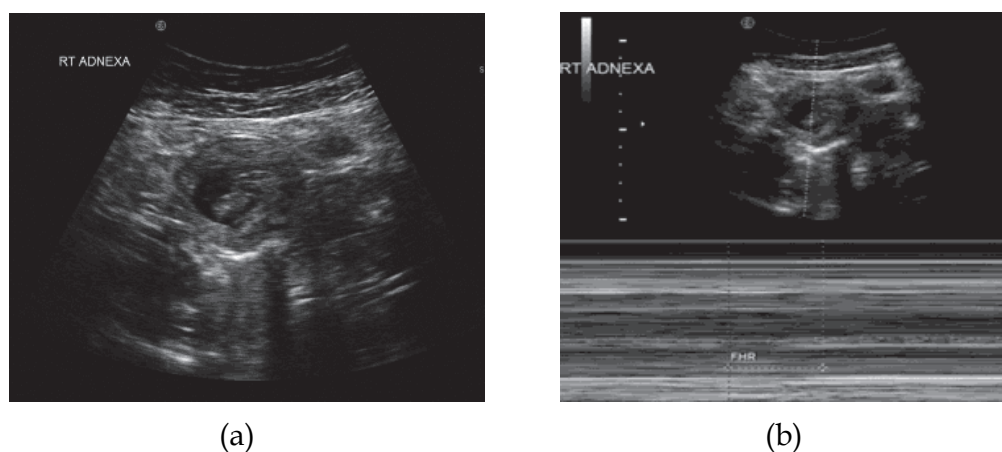


Fig. 1. (a)&(b) shows a right adnexal ectopic gestation with a live embryo demonstrated by M mode assessment of fetal heart rate (FHR).

2.1.2 Abortion

Unsafe abortion is known to account for 13% of maternal mortality (WHO 2005). Regardless of whether an abortion is spontaneous or induced, subsequent events and the care received determine whether the abortion is safe or unsafe. If an incomplete abortion is not appropriately treated, it can lead to haemorrhage, shock, sepsis and death. Ultrasound imaging is useful for obtaining definitive diagnosis, as the symptoms of incomplete abortion and ectopic pregnancy may be similar. Moreover if a miscarriage is assumed to have occurred, or termination of pregnancy is carried out without an initial ultrasound imaging, one may not know whether subsequent complaints of bleeding and pain are caused by retained products of conception, ectopic pregnancy or even a haemorrhagic corpus luteum. Additionally, early ultrasound imaging may prevent uterine perforation which can occur during evacuation of an incomplete abortion or termination of pregnancy as a result of retroverted/retroflexed uterus. Ultrasound is also useful in determining which pregnancies are viable and which are most likely to miscarry. Ultrasound findings of incomplete abortion may vary depending on the amount of products expelled; it may appear as a reduced sac-size with irregular shape, and/or an echogenic material representing placental tissue within the uterus. An irregular gestational sac without a yolk sac or embryo is consistent with a blighted ovum (Figures 2A and 2B), whereas a foetus without a cardiac activity is consistent with a missed abortion (Figure 2c).

Where available it is important to use TAS or TVS with colour and spectral Doppler application when excluding retained products of conception from a tissue that is no longer viable and is likely to be expelled spontaneously. Colour Doppler will usually demonstrate a focally increased colour Doppler flow in the region of retained products, if present.

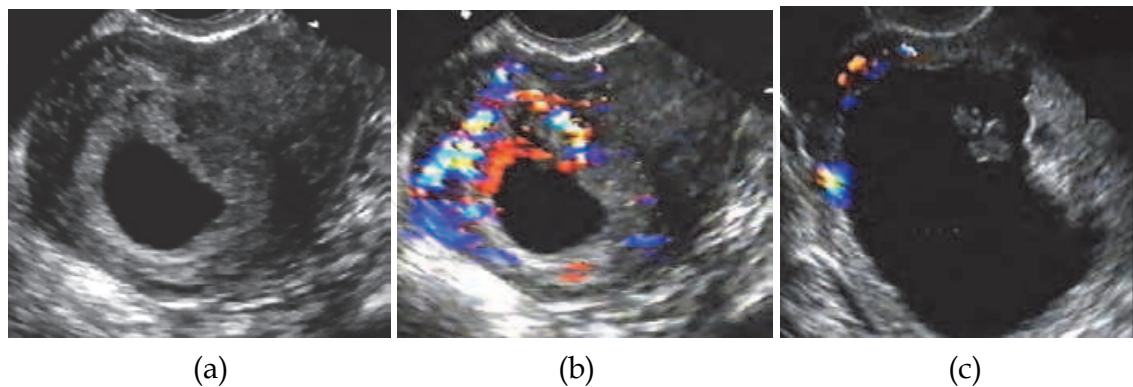


Fig. 2. (a),(b) and (c) A&B: Blighted Ovum; C: Missed Abortion- Note the non-viable embryo. In B there is increased vascularity on colour Doppler at implantation site.

2.1.3 Gestational trophoblastic diseases

Gestational trophoblastic diseases are a spectrum of benign and malignant conditions of the trophoblast comprising hydatidiform mole, invasive mole, choriocarcinoma, placental site trophoblastic tumour, and epithelioid trophoblastic tumour. Aside vaginal bleeding or brownish spotting which is common with early pregnancy conditions, molar pregnancies may present with a larger-than-date uterus, hyperemesis, passage of grape-like vesicles per vaginum, preeclampsia and hyperthyroidism. Complications of molar pregnancy can be life-threatening and include: (1) Haemorrhage from an existing mole or local invasion; (2) Anaemia due to maternal blood loss; (3) Rupture of, or haemorrhage into theca lutein cysts; (4) Pulmonary embolism or pulmonary oedema due to the migration of trophoblastic tissue through the uterine veins, and (4) Progression to malignancy.

The role of ultrasound imaging in GTDs is based on providing evidence for the diagnosis of hydatidiform mole. Once diagnosed, tumor response to therapy can also be monitored, and the presence of metastatic sites can be ascertained.

The characteristic sonographic appearance in most molar pregnancies is the demonstration of hydropic villi. The typical sonographic appearance of a complete mole is that of a complex and echogenic intrauterine mass containing many small cystic spaces, which correspond to the hydropic villi on gross pathology (Benson et al, 2000) (Figure 3a). One may also see a large, central fluid collection that mimics an anembryonic gestation or abortion (Figure 3c -& d). Occasionally, there is merely a central mass of variable echogenicity. Colour Doppler sonography is used to detect areas of increased blood flow within the myometrium (Kawano, et al, 1996) (Figure 3b) and can be used as a means of monitoring the effectiveness of chemotherapy (Bidzinski et al, 1999). Even though best practice requires that all products of conception from non-viable pregnancies should be examined histologically, irrespective of ultrasonographic findings, ultrasound will in the first place determine whether the pregnancy is viable or not. This does not downplay the importance of ultrasound in this condition. Secondly in rural settings access to histological report may delay, or may not be available at all. Ultrasound imaging will therefore assist in the initial diagnoses and in carefully selecting those

patients at higher risk for malignancy for histological evaluation, especially where the laboratory facilities for histology are not available.

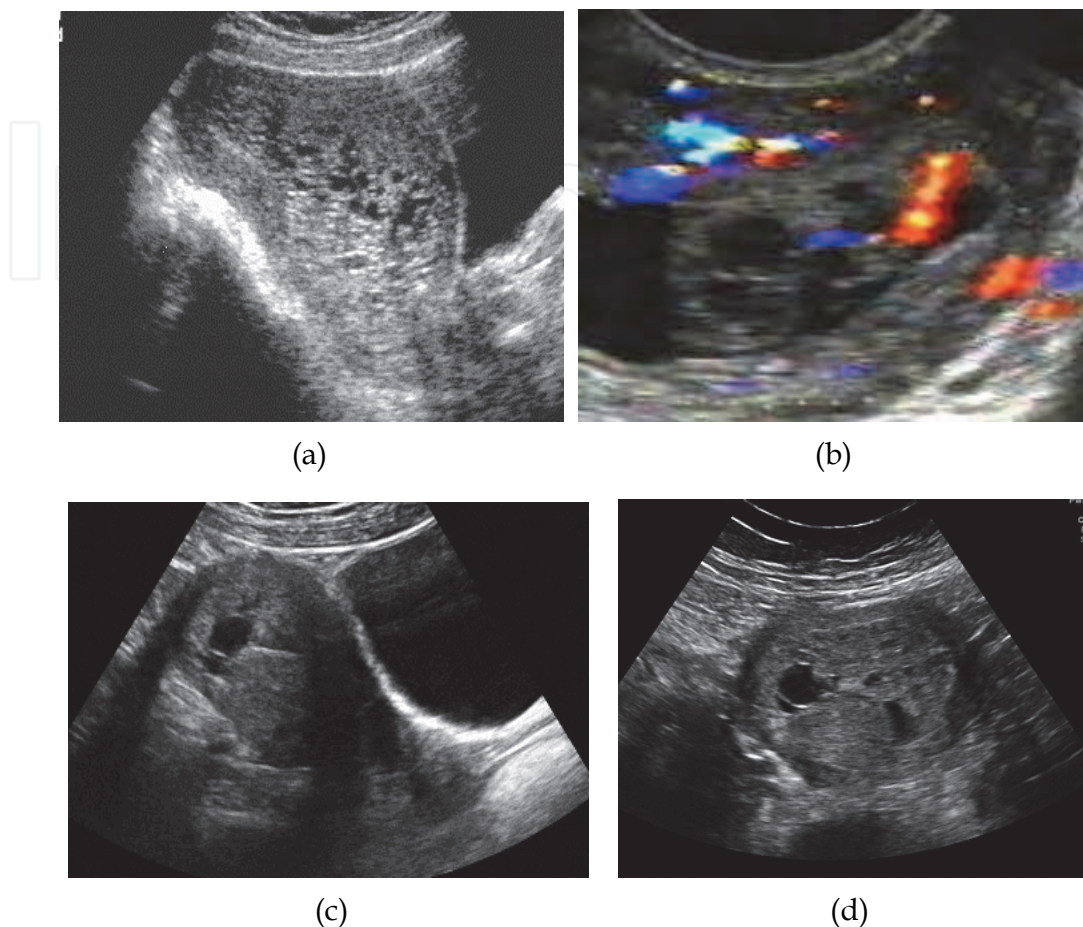


Fig. 3. (a) is a typical appearance of complete mole as described in the text
(b) shows increased flow within myometrium in regions of invasion of a mole
(c) & (d) are sagittal and transverse views of the same case respectively, showing atypical appearance of molar pregnancy

2.2 Gestational age estimation

In the first trimester a patient can benefit from ultrasound imaging in the estimation of gestational age (GA), particularly those who cannot recall their last menstrual period (LMP), or those who do not have regular 28 day menstrual cycle. Gestational age has emerged as one of the most important predictors of perinatal mortality (Markestad et al, 2005). The outcome of pregnancy is more closely related to gestational age as determined by ultrasound imaging. Accurate GA enables future detection of intrauterine growth restriction (IUGR), large for gestational age (LGA), and also essential in decision making for delivery or conditions such as premature rupture of membrane (PROM), postdates, placenta previa, hypertensive disorders, etc. The most accurate estimation of GA therefore, is done in the first trimester (7-13weeks gestation) using the crown-rump length (CRL), and is even more reliable than using clinical date (Eik-Nes et al, 2000). A CRL is determined by measuring the maximal straight line distance from the fetal head to the rump (Figure 4a & b).

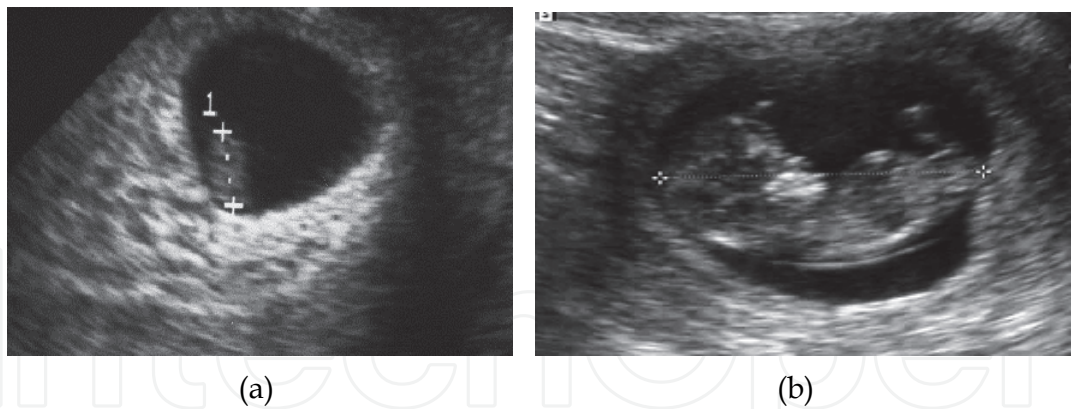


Fig. 4. CRL measurement can be used for pregnancy dating in early first trimester as figure 4a, and late first trimester as figure 4b. This is the most accurate way to date a pregnancy

2.3 Multiple pregnancy

Ultrasonography is the diagnostic tool of choice for detecting a multiple pregnancy (as early as five weeks gestation) using TVS. The perinatal mortality rate in twins is about 5-times higher than in singletons, with higher incidence in monochorionic (5%) than dichorionic (2%) twin pregnancies (Sebire et al 1997). Again, the prevalence of pre-eclampsia is about 4-times greater in twin than in singleton pregnancies (Savvidou et al 2001). Other complications include increased risk of miscarriage and pre-term delivery. There is increased risk of placenta previa, malpresentation, and abruptio placenta. Anaemia is three times more common compared to singletons. The risk of atonic postpartum haemorrhage is also far higher in twins. Also, there is increased risk of operative intervention to the mother. Increased surveillance in the antepartum period is therefore required, making early detection by ultrasound imaging an appropriate practice.

In the first trimester, dichorionic twins can easily be distinguished by the presence of a thick septum between the chorionic sacs; the septum forms the chorionic component of the inter-twin membrane. This septum becomes thinner as the pregnancy progresses, but remains thicker and easier to identify at the base of the membrane as a triangular tissue projection, the so-called lambda sign (Sepulveda et al 1996). Sonographic examination of the base of the inter-twin membrane for the presence or absence of the lambda sign (Figure 5) provides reliable distinction between dichorionic and monochorionic pregnancies. This definitive diagnosis of chorionicity may not be possible with second and third trimester scans; hence the importance of first trimester scans.

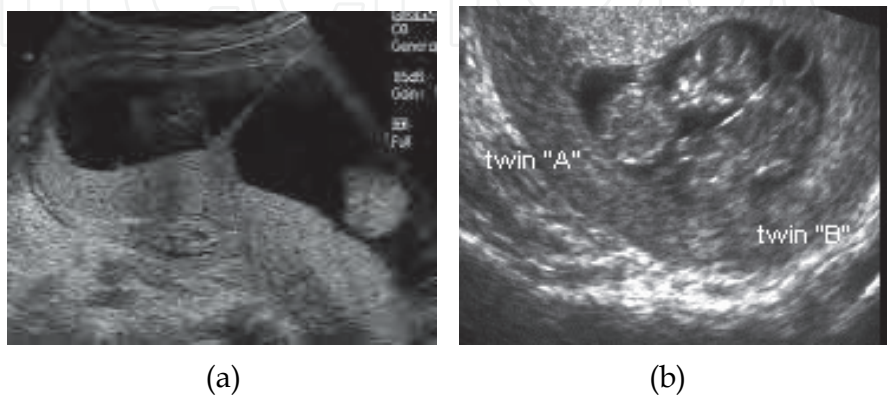


Fig. 5. (a) shows the triangular tissue projection (lambda sign). This is absent in figure 5b

2.4 Early detection of chromosomal and structural anomalies (11-14weeks'-scan)

Late first trimester ultrasound imaging for anomaly detection is typically performed at 11-14 weeks primarily for measuring nuchal translucency (NT). The NT is ultrasound description of a subcutaneous physiologic fluid collection between the skin and the cervical spine of the foetus which can be used for obtaining diagnostic information when the CRL of the foetus is 45 - 84mm (figure 6a & b) NT increases with GA hence accurate CRL is needed for interpretation of NT measurement.

Measurement of the NT is useful for determining aneuploidy, a major cause of perinatal mortality. At 11 - 14 weeks, all major chromosomal defects are associated with increased NT thickness (Nicolaidis et al 1992). In a chromosomally normal fetus, increased NT thickness is also associated with major abnormalities of the heart and great vessels, diaphragmatic hernia, exomphalos and asphyxiating thoracic atrophy (Souka et al, 2004). Further sonographic evaluation with echocardiography and/or 3D imaging may therefore be requested to rule out these anomalies. Other defects detectable at this gestational age are: acrania, anencephaly, encephalocele, gastroschisis, cleft palate, etc.

The role of ultrasound imaging in early prediction of aneuploidy and structural defects reduces the number of perinatal deaths resulting from birth defects, as it offers the couple an opportunity to decide whether or not to terminate the chromosomally abnormal fetus. Termination of pregnancy at this early gestation is associated with less maternal morbidity and mortality.

In developed countries, the practice of early termination of chromosomally abnormal foetus has significantly reduced perinatal mortality (Briker et al, 2000), and may become useful in developing countries; since with increasing education, women in these countries are now giving birth later in life, putting them at greater risk of having chromosomally abnormal babies.

Invasive prenatal testing by amniocentesis or chorionic villous sampling, which is needed for a definitive diagnosis, also requires ultrasound guidance. This invasive procedure can unfortunately result in the miscarriage of a normal pregnancy.

The important role of ultrasound, therefore, is based on the fact that most foetuses with chromosomal abnormalities have either major structural malformations or minor abnormalities (markers) that can be sonographically detected at this early stage of pregnancy (Nicolaidis, 1993), and enable termination of pregnancy with less morbidity and mortality.

Even if the couple decides to keep the pregnancy, the knowledge of structural defects enables referral to a tertiary centre to improve post-delivery care.

Table 1 show first trimester anomalies (markers) associated with aneuploidy, based on the reported findings of Nicolaidis (2004).

Even though NT can be accurately measured with TAS in about 95% of cases, where TAS assessment of NT and structural abnormalities are inclusive, a combination of TAS and TVS is required. The advantage of TAS is that it allows flexibility of probe manipulation. However, TVS offers better resolution and visualisation.

In a study by Braithwaite et al, which compared foetal anatomy at 12 to 13 weeks using TVS and TAS, they found that a complete survey of the anatomy was possible in 72% of women using TAS, 82% with TVS, and 95% by combining the two (Braithwaite et al. 1996).

Additional sonographic findings by M-mode assessment of fetal heart rate is also useful for predicting aneuploidy in the late first trimester ultrasound imaging. The normal fetal heart rate (FHR) increases from about 100 bpm at 5 weeks of gestation to 170 bpm at 10 weeks, and then decreases to 155 bpm by 14 weeks (Nicolaidis et al, 2004). At 10-14 weeks, trisomy

13 and Turner’s syndrome are associated with tachycardia, whereas in trisomy 18 and triploidy there is fetal bradycardia (Liao et al 2001). In trisomy 21, there is a mild increase in FHR (Nicolaides et al 2004).

The detection rate of the additional structural abnormalities, some of which are listed in table 1, depends very much on the skill and experience of the sonographer, and to a lesser extent on the machine. With state of the art ultrasound machine many structural abnormalities have been detected in recent years. In five separate studies of screening an unselected population in the first trimester, the detection rates of fetal abnormality ranged from 33%-64.7% (Peregrine and Pandya, 2005).

The importance of 3-D ultrasound imaging especially in high-risk families further enhances detection of abnormality (Pretorius et al, 1995). Some investigators have suggested that 3-D ultrasound imaging is the tool of choice in evaluating the skeletal structures and the thorax, especially the long bones, due to capability of rotating the volumes (Ploeckinger-Ulm et al, 1996). However, fast movement of the foetus, and the positioning of the extremities adjacent to the uterine wall, can potentially be an obstacle in their evaluation. Although 4-D imaging may prove to be more useful, the primary stumbling blocks remain the same.

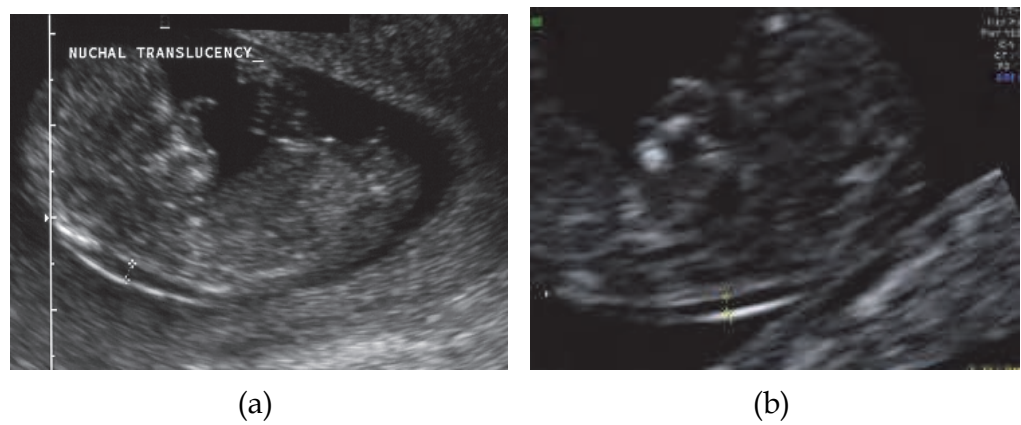


Fig. 6. (a)-(b) shows the NT region; zoom the image closer as in 6b for a clear visualization of the NT space.

Aneuploidy	Ultrasound findings
Trisomy 21	Absent nasal bone(60-70% of cases), short maxilla (25% of cases), Abnormal ductus venosus waveform (80% of cases)
Trisomy 18	Absent nasal bone (55% of cases), Single umbilical artery (75% of cases), exomphalos (30% of cases), bradycardia and early onset of fetal growth restriction
Trisomy 13	Holoprosencephaly, tachycardia (70% of cases), exomphalos (40% of cases), megacyst, and early onset of fetal growth restriction
Turner’s syndrome	Tachycardia (50% of cases), and early onset of fetal growth restriction
Triploidy	Holoprosencephaly, exomphalos, bradycardia (30% of cases), posterior fossa cyst (40% of cases), molar changes in placenta (30% of cases), and early onset of fetal growth restriction

Table 1. Sonographic markers for aneuploidy in first trimester

3. Reducing mortality rates by ultrasound imaging in the second trimester

Second trimester ultrasound imaging is typically performed between 18 and 24 weeks of gestation. Ultrasound imaging is performed to evaluate fetal and maternal structures for abnormalities that could lead to maternal and/or perinatal mortality. The structures evaluated are fetal anatomy, fetal biometry, amniotic fluid volume, placenta, maternal cervix and Doppler velocimetry of uterine and umbilical arteries. The purpose is to exclude findings associated with fetal chromosomal abnormalities, pre-term delivery, IUGR and pre-eclampsia. Pre-eclampsia and intrauterine growth restriction remain the two most important causes of maternal and neonatal death that need to be detected as early as possible (Sibai, Dekker, Kupferminc, 2005; Walker, 2000). These 2 conditions are thought to be the result of abnormal placentation in which there is failure of trophoblastic invasion of the spiral arteries resulting in increased vascular resistance in the uteroplacental circulation (Pijnenborg et al, 1991).

Pre-eclampsia can cause serious maternal complications including the HELLP syndrome (microangiopathic Hemolysis, Elevated Liver enzymes, Low Platelet count), eclampsia, coagulopathy, stroke and death (Wen et al, 2005; Roberts JM and Cooper DW, 2001).

Early prediction of pre-eclampsia and intrauterine growth restriction by ultrasound imaging in the second trimester is therefore paramount to providing appropriate antenatal surveillance and therapy in an effort to improve pregnancy outcomes. It must be pointed out, however, that prediction of these conditions in the second trimester is only possible if accurate dating from either early ultrasound examination or known conception dates has been previously established.

3.1 Assessment of fetal anatomy in the second trimester

The use of ultrasound imaging to exclude fetal structural defect in the second trimester has been a common practice in most developed countries for sometime. Over the past decade researchers have identified specific structural defects/markers and their specific syndromal pattern of abnormalities, most of which have been listed in table 2. The overall risk of chromosomal abnormalities increases with the total number of defects that are identified (Nicolaidis et al, 1992). Considering that birth defects are among the list of common causes of perinatal mortality, detection of these defects by ultrasound imaging assists mothers to know their risk of chromosomal abnormalities. Based on the ultrasound findings they can consider termination, particularly if the mother's conditions such as age, medical history, and previous pregnancies, puts her at risk of losing her own life. In resource-poor countries where expensive invasive procedures such as amniocentesis may not be cost-effective or readily available, ultrasound imaging may be the only affordable modality for determining a woman's risk of delivering a chromosomally abnormal baby who is more likely to die in the perinatal period than a chromosomally normal baby, so that they might consider termination. Even in pregnant women with high risk factors who can afford invasive procedures, ultrasound imaging is still indicated, as the initial less expensive and non-invasive procedure before ultrasound-guided amniocentesis is considered. If no defect is detected on ultrasound imaging, the mother's risk of chromosomal abnormality is reduced, and she may decide not to proceed with an amniocentesis procedure with its associated risk of miscarriage.

3.2 Assessment of fetal size (biometry)

Second trimester clinical determination of gestational age/fetal size using LMP and uterine size are rather subjective. This is because clinical dating can be negatively affected by wrong information on LMP, maternal body habitus, fibroids and multiple pregnancy.

The indication for ultrasound imaging, however, may be requested, not just for estimating gestational age (and date of delivery), but more importantly, to exclude intra-uterine growth restriction (IUGR).

SYNDROME	COMMON ULTRASOUND FINDINGS
Trisomy 21	Brachycephaly, mild ventriculomegaly, flattening of the face, nuchal edema, atrioventricular septal defects, duodenal atresia and echogenic bowel, mild hydronephrosis, shortening of the limbs, sandal gap and clinodactyly or mid-phalanx hypoplasia of the fifth finger.
Trisomy 18	strawberry-shaped head, choroid plexus cyst, absent corpus callosum, Dandy-Walker complex, facial cleft, micrognathia, nuchal edema, heart defects, diaphragmatic hernia, esophageal atresia, exomphalos, renal defects, myelomeningocele, growth retardation and shortening of the limbs, radial aplasia, overlapping fingers, and talipes or rocker bottom feet
Trisomy 13	Holoprosencephaly, microcephaly, cardiac abnormalities, enlarged and echogenic kidneys, exomphalos and postaxial polydactyly
Triploidy	IUGR, molar placenta, mild ventriculomegaly, micrognathia, cardiac abnormalities, myelomeningocele, syndactyly, and ‘hitch-hiker’ toe deformity.
Turner syndrome	cystic hygromata, generalized edema, mild pleural effusion and ascites, and cardiac abnormalities

Table 2. Sonographic markers for aneuploidy in second trimester

Many sonographic parameters have been used for estimating gestational age in the second and third trimesters. The commonly used parameters are: fetal head circumference (HC) and biparietal diameter (BPD), abdominal circumference (AC) and femur length (FL). The measurements obtained from these parameters are used in conjunction with other sonographic findings including oligohydramnios (subjectively assessed) and the placental size and echotexture. In twin pregnancy, twin-to-twin transfusion can also be determined by measuring the size of the fetuses using the same parameters stated for assessing each fetus.

3.3 Assessment of placenta

Evaluation of the placental size, location and the retroplacental area should be part of every antenatal ultrasound examination performed in the second trimester. Placental size is a reflection of the health and size of the fetus and correlates with pregnancy outcome (Dawn, 1995; Theam et al, 2001). Also, there is positive correlation between placental volume and neonatal birth weight and babies length (Sivaro et al, 2002). The size is estimated by either measuring the placental thickness or its volume (Geirsson et al., 1985). A thin placenta (<10mm) may be due to IUGR, placental infarction, or pre-clampsia (Chase and Cayea, 1991). In recent times, the development of 3D ultrasound has improved the clinical ability to obtain a placental volume measurement (Jurkovie et al., 1994).

Secondly, placental previa must be excluded. Placental previa refers to a placenta that is close to the maternal internal cervical os, or covers the os either partially or completely.

It is a dangerous and sometimes fatal condition for mother and/or baby due to the possibility of severe haemorrhage. Accurate and timely diagnosis of placenta previa is therefore indispensable. Fortunately, major degrees of placenta previa are easily recognised by ultrasound imaging around 18-20 weeks gestation. Although TAS imaging may be unable to see the precise relationship between the lower placental edge and the internal os in cases of suspected minor previa, further TAS evaluation in the third trimester will usually delineate the placental site, and should be performed first with a partially filled bladder and then with an empty bladder, to avoid false positive diagnoses. Where concerns persists, a TVS in the third trimester will accurately define the relationship between the lower edge of the placenta and the internal cervical os (Figure 8b). As a general guide, a placenta-internal os distance of $>2\text{cm}$ is required for safe vaginal delivery.

Another important concept in ultrasound imaging of the placenta is observation of the retroplacental hypoechoic complex which is composed of uteroplacental vessels, myometrium and decidua. Absence of the hypoechoic space may be seen in placenta percreta, a condition where the placenta has invaded the whole myometrial thickness. It is therefore logical to exclude placental percreta in pregnant women at high risk, as it could result in severe hemorrhage and maternal death.

3.4 Assessment of maternal cervix

Assessment of the cervix can assist in management decisions by predicting those patients who are at risk of preterm birth. Shortening of the cervix (Iams et al, 1996; Welsh A, Nicolaides, 2002) or dilatation/funneling of the internal os (Guzman et al, 2001) is associated with increased risk of premature delivery. Early prediction is important because premature birth is responsible for 75% of neonatal mortality and morbidity (Iams JD, 2003). In the past, clinical examination was the only method available for evaluation of the cervix.

However, clinical examination is subjective. This is especially true when it comes to estimation of the length of the cervix. Furthermore, detection of changes in the internal cervical os or cervical canal is impossible with a closed external os. When cervical dilatation or shortening of the cervix is noted by ultrasound imaging, cervical cerclage (and sometimes conservative management with bed rest) can help reduce the likelihood of premature births that are caused by cervical incompetence, thereby reducing perinatal mortality.

There are three approaches to scanning the cervix: TAS, TVS and transperineal (translabial). TVS approach is the gold-standard technique for optimal imaging, and should be employed when imaging by the TAS approach is suboptimal. Generally in our practice TAS approach has been accurate in the second trimester, but difficulty may occur in the third trimester as the pregnancy advances which may require the use of TVS. In assessing the cervix with TVS, scan gel is applied to the tip of the transvaginal transducer, which is then covered with a clean or sterile condom or glove to avoid cross infection. Lubricating gel is applied over the cover and the transducer tip is introduced into the vagina, about 2-3cm depth and away from the cervix. Sonographic visualization starts as soon as the transducer is introduced. Inserting the transducer tip too far can cause the examiner to miss seeing the cervix and lower uterine segment as the transducer tip reaches the posterior or anterior fornix. The cervical length is measured by orienting the transducer in the sagittal plane (figure 8a). The transducer is then oriented in the coronal plane to assess the internal os

and the canal for further evaluation of any dilatation, funneling of the internal os, or ballooning of the lower uterine segment which may appear as a bulging of amniotic fluid sac into the cervical canal.

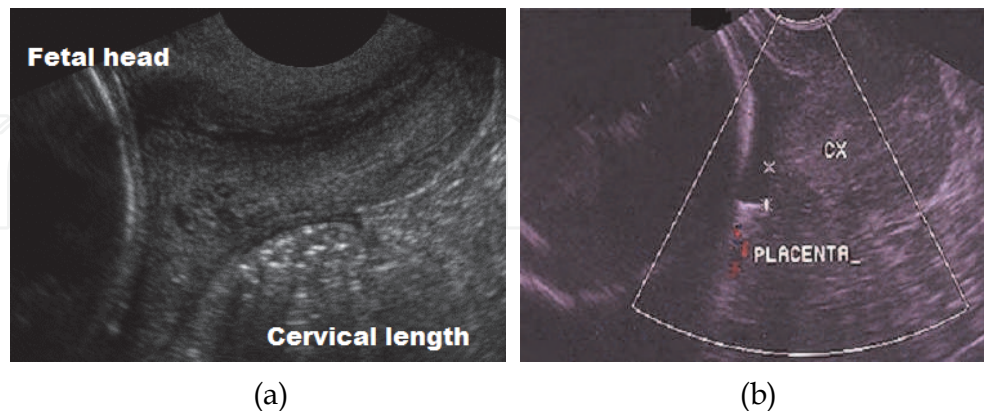


Fig. 8. (a) and (b) - TVS demonstration of cervical length. Measurement of the distance of the placenta from the internal os can be made

3.5 Doppler velocimetry of the second trimester

Doppler assessment of uterine and umbilical arteries is a reliable technique for predicting the level of risk for preeclampsia and intrauterine growth restriction, preterm delivery, gestational diabetes and fetal asphyxia (Martin et al, 2001, Reese et al, 1994; Bromley et al, 1994). Uterine artery assessment may be performed via the TVS or TAS route in the second trimester (18-22weeks) for high risk population. A high resistance waveform in uterine artery, or a waveform with a notch (Figure 9), implies inadequate trophoblastic invasion of the endometrial and myometrial spiral vessels.

Umbilical artery assessment is performed via the TAS route. Increased umbilical artery systolic/diastolic (S/D) ratio, or reduced diastolic flow, is also an indication of a rising placental vascular insufficiency. The diastolic flow may eventually disappear (figure 10a) or may even reverse in direction (Figure 10b), indicating that events may lead to intra-uterine death. These are clinically significant findings for uteroplacental vascular resistance associated with risk of hypertensive disorders, small for gestational age, preterm delivery, and gestational diabetes. Early detection improves management leading to improved survival.

4. Reducing mortality rates by ultrasound imaging in the third trimester

Maternal death may occur in the third trimester of pregnancy due to conditions such as antepartum hemorrhage, hypertensive disorders, thromboembolism, chorioamnionitis, cardiac disease, anaemia (sickle cell disease), rupture of uterine scar, etc.

Perinatal mortality may also be caused by conditions such as prematurity, macrosomia, IUGR, infections, maternal diabetes, and maternal isoimmunisation. Additionally, all the major causes of maternal death may also lead to perinatal death.

Ultrasound imaging plays a role in the assessment of fetal growth and well being, fetal presentation, placental location, ultrasound-guided procedures; all of which are useful for management decisions if an intervention should be carried out to improve survival rates.

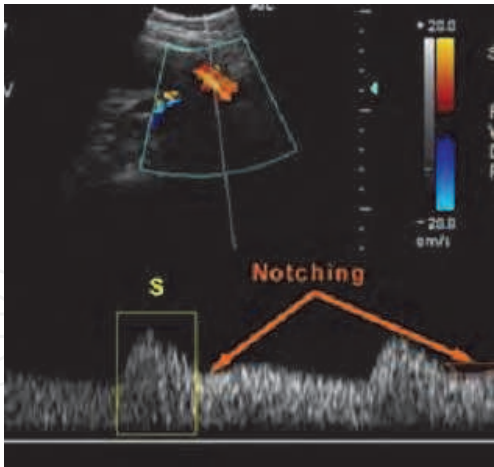


Fig. 9. Uterine artery waveform with a notch.

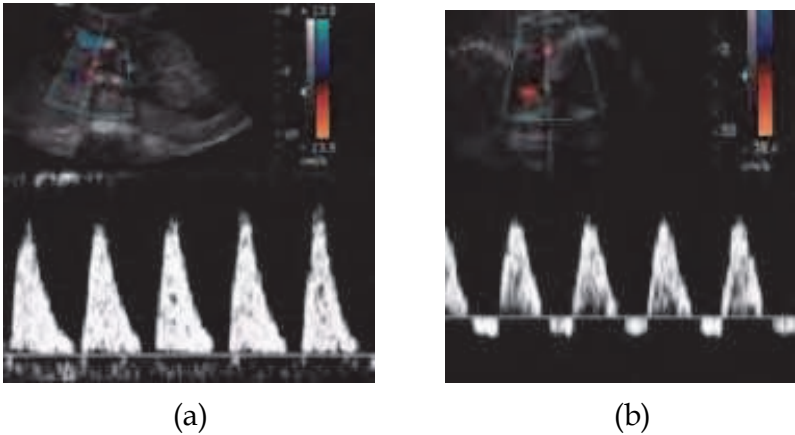


Fig. 10. (a)-(b) Umbilical artery waveform; a (absent diastole) and b (reversed diastole)

4.1 Disproportionate fetal growth (IUGR and LGA)

Perinatal death may occur in cases of IUGR due to increased risk of fetal hypoxia and acidosis, neonatal hypoglycemia, meconium aspiration syndrome, etc. Serial ultrasound examinations are important in documenting growth and excluding structural anomalies. Accurate early dating of the pregnancy is very important for comparison purposes. It must be emphasized again that the establishment of conditions such as IUGR later in a pregnancy is only possible if accurate dating from either early ultrasound examination or known conception dates has been previously established. Once true dating of the pregnancy has been established, measurements of the fetal head (BPD and HC), abdomen (AC) and femur (FL) may be obtained for comparison purposes. From these measurements, the estimated fetal weight (EFW) can be calculated using one of several published formulae on EFW. This is then plotted on a percentile growth chart, showing the estimated fetal weight versus gestational age. IUGR is suspected if the estimated weight is below the 10th percentile. Antenatal diagnosis of IUGR is however not precise because the EFW cannot be directly measured, but calculated from a combination of measured parameters with a prediction error rate 10-20% (Degani, 2001). Abdominal circumference measurement is the most useful measurement for evaluating fetal growth, as

it reflects the volume of fetal subcutaneous fat and the size of the liver which in turn correlate with the degree of fetal nutrition. Moreover, fetal hypoxia is more common when the abdominal circumference is below the 5th percentile (Degani, 2001).

Decreased amniotic fluid volume is clinically associated with IUGR and may be the earliest sign detected on ultrasound. Therefore liquor volume measurement should be carried out in cases of suspected IUGR. In the third trimester, amniotic fluid index (AFI) is the most commonly used method of amniotic fluid volume assessment, as it is easy to perform and is reproducible. This is the sum of the largest vertical pocket of amniotic fluid measured in centimetres in each of the four quadrants of the uterus. The deepest (largest) vertical pocket is used for the assessment, particularly in multiple pregnancies. In twin pregnancies measurement of the deepest vertical pocket of each individual fetus is taken. An AFI of less than 5cm, or a largest single vertical pocket of less than 2cm is considered oligohydramnios.

In addition, umbilical artery (UA) Doppler velocimetry can estimate the likelihood of adverse perinatal outcome in IUGR fetuses, and may be useful in determining the intensity of fetal surveillance. In the early phase of fetal hypoxia retrograde diastolic flow in the UA is a sign of severe hypoxemia and acidemia (Baschat and Weiner, 2000). Doppler flow study is therefore helpful in terms of reducing intervention and improving the overall fetal outcome.

In addition, abnormal middle cerebral artery (MCA) and UA S/D ratio are strongly associated with low birth weight and low umbilical artery pH in fetuses with suspected IUGR, and occurrence of fetal distress. An abnormal Doppler cerebro-placental ratio, (i.e. MCA pulsatile index divided by UA pulsatile index) also has been associated with a statistically significant increase in perinatal mortality (Sterne et al, 2001). In addition to the AU and MCA, the descending aorta has an altered perfusion in fetuses with both IUGR.

A careful and targeted ultrasound examination is therefore necessary to determine the degree of fetal well being using these sonographic parameters.

On the other hand, LGA fetuses, defined as fetuses above the 90th percentile of weight for any specific gestational age, are also associated with increased perinatal mortality. Generally macrosomia is when the fetus has an EFW of 4.5kg or more. The risk of perinatal morbidity and mortality is greater for babies with birth weight of 4kg or more. Causes of macrosomia include diabetes, obesity, postdatism and previous macrosomic babies. Complications include stillbirth, shoulder dystocia (during delivery), birth trauma, etc.

4.2 Hypertensive disorders in pregnancy

Hypertensive disorders are among the 5 most common causes of maternal mortality in the world, and the leading cause in the authors' center. This disorder comprise gestational hypertension, pregnancy induced hypertension that may progress to preeclampsia (mild or severe) and eclampsia, chronic hypertension, chronic hypertension with superimposed preeclampsia and/or superimposed eclampsia.

Ultrasound imaging is useful in preventing maternal and perinatal mortality due to accurate dating of gestational age, especially when obtained in the first trimester. Ultrasound is also used for monitoring fetal growth and well being to enable early intervention when necessary.

Moreover, with an accurate gestational age of 32-34 weeks, delivery can be effected if any maternal or fetal complication sets in, once there is very high chance of neonatal survival.

The role of ultrasound in antenatal fetal monitoring therefore, is through biometric measurement to detect IUGR, EFW, biophysical profile (BPP) and Doppler velocimetry to evaluate uteroplacental blood flow and fetal circulation.

The biophysical profile (BPP) is a useful method of predicting antepartum fetal acidemia. Studies in centers at 4 different geographic locations demonstrated reduction in perinatal mortality in high risk patients who were managed on the basis of BPP (Harman, 2005). Although the BPP test can be used as a primary method of fetal surveillance, it can be especially helpful in cases where the non-stress test (NST) is not reactive. There is some evidence that the BPP may even be useful during labour as an adjunct to fetal heart rate monitoring (Kim et al, 2003). The five components of a BPP integrate fetal cardiac activity, amniotic fluid assessment, fetal breathing, fetal movement and tone. Each component is scored 2 if present or reassuring and 0 if abnormal. Fetal breathing is the first parameter affected, and is probably as reliable as the NST in predicting early fetal acidosis. As the insult becomes more profound and chronic, fetal breathing, then body movement, then tone are compromised. The amount of amniotic fluid reflects the placental health as well as fetal well being, and is a marker for chronic hypoxia when reduced. The fetal health can therefore be accurately predicted, allowing the pregnancy to continue with low risk of fetal loss and long term morbidity if the score is normal. Timely intervention can be executed when fetal compromise is detected, to lower perinatal mortality. A BPP test can be completed in as little as five minutes if the fetus is active and awake, or can take as long as 30 minutes. Stimulation of the fetus by shaking the probe is appropriate for shortening the time of the study.

4.3 Antepartum haemorrhage (placenta previa, abruption and vasa previa)

Placenta previa can lead to severe hemorrhage and profound shock in the antenatal period, during delivery and immediately after delivery.

Perinatal death may occur in cases of placental previa due to the likelihood of preterm delivery, severe malformations in central nervous, cardiovascular, or gastrointestinal systems which may occur in the process of labour and delivery, and stillbirth from maternal shock.

Ultrasound diagnosis of placenta previa was described in the section on second trimester ultrasound imaging. In the third trimester, repeat scan is recommended for all patients who were diagnosed of placenta previa in the second trimester, and new patients reporting for the first time in the third trimester with antepartum hemorrhage must be scanned.

Abruptio placenta refers to premature separation of a normally situated placenta.

After the separation bleeding may be concealed beneath the placenta with seeping into the myometrium or track down per vaginum (revealed). Concealed abruptio placentae have more severe complications. Maternal death may occur due to the likelihood of severe hemorrhage (ante- and postpartum), shock, disseminated intravascular coagulation and renal failure. Perinatal mortality is mainly due to fetal hypoxia from the premature separation of the placenta, IUGR, low birth weight, congenital malformation, and fetal anemia.

The diagnosis of abruptio placenta is usually clinical, but ultrasound can be helpful in some concealed cases with large retroplacental clot. This appears as hyperechoic, isoechoic, or sonolucent in comparison with the placenta, depending on the age of the clot. Resolving clot appears hyperchoic within one week and sonolucent within 2 weeks. Abruptio placenta may also present as an abnormal thickening or rounding of the placental edge.

However ultrasound is not an accurate tool in the diagnosis of abruption. Its main usefulness is in excluding placenta previa, as a number of placenta previa cases may also have abruption. The size of the clot, and the fetal growth and liquor volume are closely

monitored in such cases. This is useful during conservative management to achieve fetal maturity. Intervention is carried out if clot enlarges, fetal distress sets in, or severe growth restriction sets in. If IUGR sets in, ultrasound plays further role in monitoring fetal well being through BPP and Doppler velocimetry.

Vasa previa is a condition in which the umbilical vessels divide within the amniotic membrane before they reach the placenta (velamentous cord insertion). These vessels may cross the internal os below the fetal presenting part, which is called vasa previa. The vessels may rupture spontaneously and cause rapid fetal exsanguination. This condition can easily be detected by ultrasound imaging with colour Doppler application. Appropriate intervention can then be executed before rupture occurs.

4.4 Deep vein thrombosis and thrombo embolism

Pregnancy significantly increases the risk of venous thromboembolism (VTE) due to increased concentration of clotting factors (fibrinogen, factors VII, VIII, X, XII) and venous stasis. Pulmonary embolism is a common cause of death. Fatal pulmonary thromboembolism (PTE) usually occurs after delivery, more commonly following caesarean section. Majority occurs within 2 days of delivery but may occur as late as 42 days. Antenatal PTE can occur at any trimester but more common in third trimester. Clinical diagnosis of the condition is inaccurate and unreliable, and the most reliable diagnostic modality of venography (considered previously to be the gold standard) is not suitable in pregnancy due to small risk of radiation and contrast agents.

The use of duplex ultrasound imaging with compression is therefore recommended, as it is non-invasive and has a high degree of accuracy for detecting thrombus in femoropopliteal and calf veins. The iliac veins may however not be well seen during pregnancy, and may require magnetic resonance imaging. The details of the scanning techniques and the diagnostic features of thrombosed vein, are described in a separate chapter of this book.

4.5 Rh Isoimmunisation

The Rhesus (Rh) antigens are lipoproteins on the red blood cell membrane. The mother may be isoimmunized through incompatible blood transfusion or following fetomaternal hemorrhage between a fetus with incompatible rhesus status and the mother. Rh-positive fetal red cells entering into the maternal circulation will provoke antibody formation against the fetal red blood cells leading to fetal hemolysis and fetal anemia. Severe fetal anemia may result in hydropic fetus with ascites, pericardial effusion and heart failure.

To determine the severity of the anemia, duplex ultrasound imaging of the proximal third of the MCA can be estimated. High peak velocity blood flow of the MCA correlates well with severe fetal anemia (Mari et al, 2000). This test may be performed at two weeks interval in these patients, thus avoiding more invasive diagnostic interventions until there is evidence of severe anemia. If severe anemia is suspected, ultrasound-guided cordocentesis is helpful in detecting the degree of fetal anemia. Ultrasound-guided amniocentesis is also helpful, in detecting the level of bilirubin in the amniotic fluid as a measure of fetal hemolysis using spectrophotometry.

Furthermore, ultrasound plays an important role in monitoring the iso-immunized patient for hydrops through evaluation of fetal heart size, detection of pericardial effusion and fetal ascites, and measurement of amniotic fluid volume (Roman and Martin, 2007).

In terms of treatment, if the fetus is preterm, ultrasound-guided intrauterine transfusion can be performed directly into the umbilical veins (Roman and Martin, 2007). Other

interventions aided by ultrasound include aspiration of pericardial effusion and ascites, and ultrasound-guided amniocentesis to test for fetal lung maturity before expediting delivery.

4.6 Abnormal lie and malpresentation

Malpresentation can cause, birth injury and umbilical cord compression and prolapse during delivery, which can lead to perinatal death.

Ultrasound is used to confirm abnormal lie and malpresentation of the fetus, so that a decision on the route of delivery can be made. If there is no contraindication external cephalic version can be done under ultrasound guidance at 37 weeks gestation to achieve vaginal delivery.

4.7 Cesarean scar rupture

Uterine rupture carries with it a high rate of maternal and perinatal mortality and is estimated to occur in up to 4% of pregnancies with history of caesarean delivery (). This rupture may occur silently (asymptotically) in the antenatal period, commonly in the third trimester. Ultrasound has been found to be useful in diagnosing silent rupture or scar dehiscence in the antenatal period.

5. Labour, delivery and post-delivery issues

Most maternal deaths occur during labour and delivery, and most perinatal deaths are due to events that occur during labour and delivery. Causes of maternal death at this stage include: prolonged labour with its sequel of water and electrolyte imbalance, obstructed labour with sequel of water and electrolyte imbalance and uterine rupture, eclampsia, hemorrhage and thromboembolism, and complications of anesthesia for caesarean section; all of which may lead to perinatal death as well.

During delivery, perinatal death may also result from vacuum delivery complications, which include subgaleal hemorrhage, subdural hematoma, cerebral infarction, skull fracture, and neonatal jaundice (Odoi and Opare Addo, 2002). Birth injuries sustained during shoulder dystocia and breech delivery can all result in perinatal death. Almost all of these could be prevented by proper case selection, and good labour management including use of partograph.

Ultrasound imaging is helpful in the delivery process, including assessing cervical length during induction, knowing the head position and descent during labour, case selection for vagina birth after caesarean section (VBAC), detection of uterine rupture, preventing obstructed labour, identifying cause of intrapartum hemorrhage and monitoring fetal heart.

5.1 Induction delivery interval: cervical length and dilatation

The success of labour induction is directly related to the favourability of the cervix shown by the Bishop score. Ultrasound accurately measures the cervical length and dilatation to help determine the score to avoid prolonged labour [Rane et al, 2005].

The assessment of the cervical length was described in the second trimester.

Secondly, TVS measurement of fetal head to perineum distance and, TAS measurement of fetal head position, offers the most accurate prediction of successful induction of labour [Eggebo et al, 2008].

5.1.1 Progress of labour in terms of head descent and position

Studies have shown that sonographic measurement of head position and descent is more accurate than digital examination. More recently, it has been suggested that the angle formed by a line connecting the lowest point of the fetal head to the inferior edge of the pubic symphysis provides an objective, accurate and reproducible means of assessing descent, using the translabial sonography approach. At angle of progression of about 120 degrees or more, there is a high probability of either spontaneous vaginal delivery or an easy and successful vacuum extraction [Kalache et al, 2009]. Also, the gold standard technique for assessing fetal head position during labour is transabdominal suprapubic transverse ultrasound [Sherer et al, 2002]. Therefore lack of progress as shown by partographic presentation of this sonographic finding prompts intervention.

5.1.2 Selection of cases for vaginal birth after Caesarean section (VBAC)

The main concern about VBAC is the uterine scar rupture. Predisposing factors to uterine rupture include fetal size and scar thickness. The estimation of fetal size and weight aids selection of cases. Studies have found that the antepartum uterine scar thickness inversely correlates with the risk of intrapartum uterine rupture, and that intrapartum assessment of uterine scar can predict uterine rupture with a high degree of accuracy. There is evidence that ultrasound imaging may be useful in determining the uterine scar thickness [Asakura, 2000] and aid in case selection for VBAC.

5.1.3 Detection of uterine rupture

Uterine rupture during labour and delivery is mostly diagnosed clinically; hence if clinical diagnosis is clear, precious time should not be wasted on ultrasound imaging [Yeboah et al, 2010].

However where the clinical features are not obvious, as may occur in pre-labour silent rupture, or occasionally in labour especially with epidural, ultrasound imaging may show the rent in the uterine wall [Ogbole et al, 2008], with herniated membrane as a cystic structure through the defect [Acton et al, 2004].

5.1.4 Head position for vacuum

The success of vacuum delivery depends, among other conditions, on where the cap is positioned. Wrong placement may deflex the fetal head and lead to failure of the procedure. The cap must be placed at or close to the flexion point on the vertex. Ultrasound aided examination has been shown to detect this flexion point better than digital examination alone [Wong, 2007; Molina and Nicholides, 2010]

5.1.5 Cord presentation

This condition, if not detected will lead to umbilical cord prolapse when the fetal membranes rupture. It may be difficult to feel a presenting cord. Colour Doppler sonography can clearly detect this cord to direct appropriate intervention to avert fetal or neonatal death.

5.1.6 Preventing obstructed labour

Fetal macrosomia, malpresentation and abnormal lie are all causes of obstructed labour. Apart from macrosomia, all the other conditions also predispose to cord prolapse.

Ultrasound is useful in detecting all these for appropriate intervention to prevent the obstruction or cord prolapse by assessing fetal biometry and EFW, and presentation / lie.

5.1.7 Fetal heart rate detection

Occasionally the fetal heart rate may not be heard with the Pinard fetal stethoscope.

As ultrasound is becoming more and more available than sonicaid (audio Doppler) or cardiotocography (CTG) machine, especially in low-income countries, ultrasound is used to check the fetal condition and if fetus is alive and in distress, prompt delivery by caesarean section or vacuum will prevent perinatal death.

5.1.8 Version in the second stage of labour for second twin

There is increased perinatal mortality associated with the second twin compared to the first twin due to cord accidents, premature separation of the placenta and other factors after delivery of the first twin. There is therefore the need to expedite delivery of the second twin as early as possible. After delivery of the first twin, if the second twin is not cephalic, external cephalic version (if membranes are intact) or internal podalic version (if membranes are intact or just ruptured) may be done under ultrasound guidance to achieve vaginal delivery

5.2 Post-partum complications

Uterine inversion leading to hemorrhage and shock, retained products of conception leading to hemorrhage and infection, puerperal sepsis, postpartum eclampsia, and thromboembolism are major causes of maternal death after delivery.

The usefulness of ultrasound imaging in detecting thromboembolism and the imaging technique has been discussed earlier.

In some cases of uterine inversion where clinical diagnosis is not obvious, ultrasound has been used to elicit the diagnosis [Momin et al, 2009] to enable appropriate management.

In cases of retained products of conception ultrasound can differentiate between retained products and endometritis [Zuckerman et al 1997] Even tiny retained products of conception as occurs in first trimester miscarriage is accurately detected by TVS with Doppler application [Ustunyurt et al., 2007]

5.2.1 Postpartum detection of uterine rupture

Sometimes the suspicion of uterine rupture does not arise until after delivery, especially if it occurs in the second stage of labour. There is evidence that ultrasound can detect caesarean section scar rupture after delivery (Henrich et al, 2005) and even scar defect after the puerperium (Amstrong et al, 2003). Others have suggested that a combined anterior uterine wall and bladder thickness (<3mm) associated with ballooning of the lower segment indicates a defect in the myometrium (Champmank, 1994).

5.2.2 Postpartum detection of broad ligament hematoma

Broad ligament hematoma may occur when there is uterine rupture or cervical tear with upper extension, and can cause shock in the post-partum period that may be out of proportion. Ultrasound imaging can aid the detection of the hematoma.

5.2.3 Puerperal sepsis

Apart from aiding in the diagnosis of postpartum endometritis, ultrasound accurately detects pelvic abscess, which may appear as a focal collection, either hypoechoic or complex.

6. Routine obstetric ultrasound- would it improve survival rates in the developing world?

Routine obstetric scanning refers to regular ultrasound imaging for each and every pregnancy conducted either at the first, second or third trimester to separate specific pregnancy abnormalities from normally progressing pregnancies. In many developed countries, such as Great Britain, Germany, France and those of Scandinavia, routine obstetric ultrasound imaging at about 18 weeks' has become standard of care. In United States routine ultrasound was not endorsed until recently when the American College of Obstetricians and Gynecologists (2007) recommended routine aneuploidy screening for pregnant women. One published large-scale observational study in Sweden concluded that a significant benefit could be obtained from even a single routine obstetric ultrasound at approximately 15 weeks' gestation (Waldenström et al, 1988). Among the important benefits of routine ultrasound are the accuracy in gestational age determination, and detection of multiple pregnancies (Neilson et al 1998). In most developing countries, accurate estimation of gestational age by ultrasound imaging is likely to be more beneficial and significant than developed countries, as the majority of pregnant women in those areas cannot recall their LMP (van Dyk et al, 2008) probably due to the high illiteracy rates among the pregnant women. This makes them far more vulnerable to unrecognized preterm delivery (a major cause of perinatal mortality), and post-maturity syndromes associated with fetal distress and long-term development disorders.

However, the impact of routine ultrasound imaging in terms of significantly improving the over-all pregnancy outcome has been disputed by many observational studies conducted mostly in developed countries. But considering the fact that there are no sufficient studies conducted in developing countries, it is still unclear whether the impact as described in developed countries will produce similar results in developing countries. Until then, one cannot rule out the possible impact routine ultrasound imaging can have in developing countries, as most of the victims of maternal and perinatal mortality live in these areas.

The major challenge for routine ultrasound however, has been cost effectiveness.

In England routine antenatal ultrasound screening has been estimated to cost the National Health Service (NHS) £14 to £16 per scan, while the family contribute between £9 and £15 per scan, giving an indication of how expensive routine ultrasound can be for developing countries (Henderson et al 2002). But the Canadian and most European health policy-makers support the view that the benefits of routine ultrasound outweigh the cost, and in those countries routine ultrasound screening is either a national policy or a recommendation (Saari-Kemppainen et al., 1990; Public Health Agency of Canada, 2006). Moreover, maternal and newborn deaths is said to be representing an estimated annual global financial loss of \$15 billion in potential productivity (USAID, 2001). So that if observational studies on the significant impact of routine obstetric ultrasound in developing countries should show a positive impact, there may be the need for

international support to assist in financing routine ultrasound imaging in antenatal care for developing countries, as part of efforts to reach the Millennium Development Goals on reducing maternal and neonatal deaths.

Secondly, routine ultrasound has also been criticized for prompting unnecessary intervention, creating anxiety related to false-positive diagnoses and giving false assurances to women who may be dissuaded from undergoing further examination because of a normal ultrasound. Therefore we recommend that if some form of routine ultrasound imaging will ever be considered for developing countries, then standardized guidelines will have to be in place in terms of training qualified personnel, quality assurance of ultrasound machine and regulating ultrasound practice to minimize such problems.

7. Sustainability of ultrasound imaging for the developing world

WHO has recommended ultrasound for dissemination to developing nations during the second phase of its earlier basic radiology system initiative (WHO, 1998). Ultrasound was described as a "sustainable technology" for developing and low-resource countries, because of its relatively low cost of purchase, low cost for maintenance and supplies, portability, and durability in comparison with all other imaging modalities (Goldberg, 2003). Currently the increasing availability of affordable and smaller ultrasound scanners is a clear indication of the sustainability of ultrasound for the developing world and its potential role in reducing maternal and perinatal mortality (Harris and Mark, 2009). A market survey we conducted (unpublished) revealed that a new ultrasound machine could cost as low as \$5000, and can be used for basic obstetric assessment such as gestational age, foetal viability, placental position, and may even be used for foetal anatomical survey. Further evaluation with more sophisticated and relatively expensive machines can then be arranged for selected cases with suspected anomalies, as a form of 'level 2' or 'level 3' scanning conducted by an advanced practitioner or specialist. Moreover the practice of donating slightly used but good quality machines continues to be helpful and should be encouraged.

Manufacturers of ultrasound systems must support developing countries by providing offices, sales representatives, and applications personnel in these regions, so that they can assist with the dissemination of equipment, initial installation and instruction on equipment usage, and equipment maintenance.

Lack of adequately trained physicians and sonographers, and limited means of equipment maintenance in developing countries has been a major challenge (Munjanja, 1993). Even though some developed countries around the world have made a concerted effort to provide education, it continues to be provided in a random fashion and has never been able to keep up with the need for adequate training for physicians and sonographers. One proposal at using a low cost system for training ultrasound imaging techniques has been via use of a PC platform that uses interface components from the Nintendo Wii games console (as a simulator) to aid remote mentoring by experienced ultrasound professionals. The proposers cited their experience with this technique in Ghana as an example (Ap Cenydd et al, 2009).

Another recommendation has been to incorporate a diploma in clinical ultrasound for medical graduates of local universities (Mindel, 1997). The use of existing allied health

professionals such as nurses/midwives or radiographers who have received additional training in ultrasound has been valuable in some developed countries, and may be cost-effective in developing countries. A new model in developing countries is the creation of Bachelor degree programs in Sonography in existing university settings. Graduates of these university sonography programs may be utilized as sonographers, or professionals in ultrasound imaging and may help to ease the pressure on doctors in developing countries. It is the belief of the authors that a three-pronged approach must be utilized for the sustainability of ultrasound in developing countries: First, the development of a new career path through the university setting for sonographers; Second, the creation of long-term comprehensive sonography education programs for physicians; and Thirdly, involvement of government agencies and institutions for regulatory policy setting. Clearly, creative and novel approaches that serve the unique situations of developing countries and address the need for both trained operators of ultrasound equipment and people with biotechnical skills for ongoing maintenance would be highly beneficial (Spencer and Adler, 2008).

8. Conclusion

In spite of increasing technological advancement, including ultrasound imaging, maternal and perinatal mortality globally have not decreased and indeed in some developing countries there is increase.

The major causes of maternal mortality include abortion related complications, hemorrhage from various conditions, hypertensive disorders, thrombo-embolism, obstructed labour, prolonged labour, ruptured uterus and puerperal infection. Causes of perinatal mortality include prematurity, birth asphyxia, congenital malformations, IUGR, traumatic delivery, and cord prolapsed. A significant number of these conditions that lead to maternal death also lead to perinatal death.

Fortunately, ultrasound is a non-invasive and safe tool that can aid in the diagnosis of most of these conditions, prevent the effects of these complications and in some cases guide in treatment. Thus wider use of ultrasound is advocated in obstetric practice. It is important for every medical doctor in the obstetric unit and indeed midwives to be trained in basic use of ultrasound in obstetrics. The need for advanced practice training for specialist obstetricians as sonologists, and professional sonographers as advanced ultrasound practitioners is recommended for the future in developing countries as currently practiced in some developed countries.

Governments should be committed to the purchase and maintenance of ultrasound machines for healthcare facilities, especially in obstetric units. A more widespread use of ultrasound imaging and improvement in treatment approach should lead to reduction in maternal and perinatal mortality.

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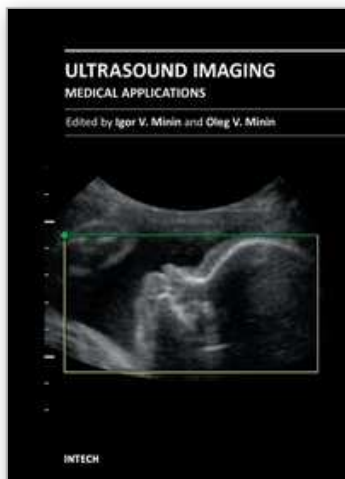
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