The role of ultrasound in obstetrics

Nicky Roberts
Basky Thilaganathan

Abstract
Advances in ultrasound technology and new developments in the field of screening for pregnancy disorders have led to a change in the clinical application of ultrasound in the routine care of low-risk pregnant women. In parallel, there has been an increased tendency to inappropriately use this technology. This review highlights the validated uses of ultrasound in obstetrics, such as pregnancy dating, screening for aneuploidy, diagnosis of fetal abnormality and placental localisation. Knowledge of the scientific basis of the role of ultrasound means less unnecessary intervention in normal pregnancies and more appropriately timed intervention in pathological pregnancies.

Keywords pregnancy; ultrasound; dating; screening; diagnosis; Down’s syndrome; preterm delivery; pre-eclampsia; growth restriction; multiple pregnancy; placenta praevia

Introduction
Ultrasound has been in clinical use in obstetrics since 1978. With advances in technology, there have been improvements in resolution, allowing better imaging of the fetus. This, together with new developments in the field of screening for pregnancy disorders, has led to a change in the clinical application of ultrasound in the routine care of low-risk pregnant women. Techniques such as pulsed wave and colour Doppler imaging have improved the monitoring of small for gestational age fetuses and help to differentiate fetuses that are well, from those that are not. This has led to less interference in normal pregnancies and more appropriately timed intervention for fetuses in genuine trouble.

The use of ultrasound in obstetrics may be broadly classified as elective or reactive. Elective or planned use implies scanning to detect potential problems in an otherwise seemingly uncomplicated pregnancy (screening), whereas reactive use is the application of ultrasound to help in the management of a clinical problem such as suspected fetal growth restriction.

Elective use of ultrasound
Pregnancy dating
Nagele’s rule predicts the mean length of gestation to be 280 days from the last menstrual period (LMP). The problems of calculating gestational age based on menstrual history are well recognised. Even if menstrual dates are considered certain or reliable, this method tends to lead to an overestimation of gestational age compared with ultrasound. Also, gestational age distributions are negatively skewed; hence, the mean value is not representative of the ‘typical’ length of pregnancy, and there have been proposals that the modal value (283 days) should be used instead. These factors result in a much wider error margin in LMP dating compared with ultrasound dating in the first half of pregnancy. For women who present in the second trimester, gestational age can be assessed by ultrasound measurement of biparietal diameter or head circumference, and this has an error deviation of about ±7 days. The first trimester is a period of rapid growth and gestational age is by far the strongest variable affecting fetal size, with the result that crown–rump length measurement is even more accurate (Figure 1).

The UK National institute for Clinical Excellence guideline on antenatal care recommends that all pregnant women should be offered an early ultrasound examination to determine gestational age (in lieu of LMP). This ensures consistency of gestational age assessments, improves the performance of screening for Down’s syndrome, and reduces the need for induction of labour after 41 weeks. Scans should ideally be performed at 10–13 weeks and should use the crown–rump length measurement to determine the gestational age.

Accurate pregnancy dating is especially important at the extremes of pregnancy. The likelihood of survival following extreme premature delivery increases steeply from about 40% at 24 weeks to more than 80% at 28 weeks. When assessing gestation, a few days variation in either direction has an impact on the baby’s chances and hence on the advice given to parents and on clinical management decisions. At the other end of the spectrum, as many as 70% of pregnancies presumed to be post-term (>294 days) by menstrual dates are not post-term by scan dates. This suggests that most inductions for post-term pregnancy could be avoided on the basis of ultrasound estimation of gestational age alone.

In terms of prenatal screening, both nuchal translucency and biochemical test levels (serum α-fetoprotein (α–FP) and β-human chorionic gonadotropin (β-hCG)) vary with gestational age. Erroneous dating therefore leads to incorrect risk assessment, unnecessary referrals and increased maternal anxiety.

Multiple pregnancy
Twins account for about 1% of all pregnancies; two-thirds are dizygotic and one-third monozygotic (identical). In dizygotic pregnancies, each zygote develops with its own chorion (dichorionic). Monozygotic pregnancies may also be dichorionic, or there may be sharing of the same placenta (monochorionic) and even fetal organs (conjoined). Chorionicity and amnionicity depends on how soon the single embryonic mass splits after fertilisation. The perinatal mortality rate in twins is around six times higher than in singletons, and the increased mortality is about 3–4 times higher in monochorionic than dichorionic twin pregnancies, regardless of zygosity. Perinatal statistics actually underestimate the importance of monochorionic placentaion in fetal death, since the highest rate

Nicky Roberts is a Clinical Fellow in the Fetal Medicine Unit, St George’s Hospital, London, UK.
Basky Thilaganathan is Reader in Obstetrics and Director of Fetal Medicine, Fetal Medicine Unit, St George’s Hospital NHS Trust, London, UK.
of mortality is before 24 weeks of gestation due to twin-to-twin transfusion syndrome (TTTS). Any effort to reduce this excess loss can be achieved only through early identification of monochorionic pregnancies by ultrasound examination in early pregnancy and the development of appropriate methods of surveillance and intervention during the second trimester.

Chorionicity can be determined by ultrasonography and relies on the assessment of fetal gender, number of placentas and the characteristics of the inter-twin membrane. Different-sex twins are dizygotic and therefore dichorionic, but in about two-thirds of twin pregnancies the chorionicity cannot be determined in this way, as the fetuses are of the same sex. Similarly, if there are two separate placentas, the pregnancy is dichorionic, but if the two placentas are adjacent to each other, it is often difficult to differentiate them.

The best way to determine chorionicity is by an ultrasound examination at 6–9 weeks of gestation, when in dichorionic twins there is a thick septum between the chorionic sacs. After 9 weeks, this septum becomes the inter-twin membrane, but it remains thick and easy to identify at the base of the membrane as a triangular tissue projection. This, when visible, is known as the lambda sign. With the introduction of first-trimester scanning at 11–14 weeks, ultrasonographic examination of the base of the inter-twin membrane for the presence or absence of the lambda sign provides a reliable distinction between dichorionic and monochorionic pregnancies (Figure 2).

TTTS is thought to occur in about 15% of monochorionic twins and is not usually detectable before 16 weeks of gestation. TTTS describes a wide range of problems that can occur in monochorionic twins as a result of unequal sharing of placental blood through inter-twin vascular anastomoses. Ultrasound features in the donor include fetal growth restriction, an empty bladder and anhydramnios. In contrast, the recipient usually has normal growth velocity, a large bladder, polyhydramnios and, when TTTS is severe, hydrops. Untreated severe TTTS before 26 weeks is associated with perinatal mortality of up to 90% and a high risk of disability in the survivors. A large, multi-centre randomised study has shown that fetoscopic laser coagulation of inter-twin anastomoses is a more effective first-line treatment than serial amnioreduction in cases of severe TTTS at less than 26 weeks.

Placental site
Placental implantation in the lower uterine segment (placenta praevia) is an uncommon but serious complication of pregnancy. A low-lying placenta is often diagnosed (15–20% of cases) following mid-trimester ultrasonography. The prevalence of clinically evident placenta praevia is estimated to be approximately 4–5 per 1000 pregnancies (Figure 3).

The diagnosis of placenta praevia is based on the findings of the ultrasound examination before the occurrence of symptoms. It is well established that the use of transvaginal ultrasound is superior to transabdominal ultrasound in defining the relationship of the placental edge to the internal cervical os. Also, the use of ultrasound has changed the classification of placenta praevia to ‘minor’ and ‘major’. A minor placenta praevia (low-lying placenta) is one that lies in the lower uterine segment more than 2 cm from the internal os. A major placenta praevia occurs when the placental edge overlaps or is within 2 cm of the internal cervical os in late pregnancy.

If the placenta is overlapping or reaching the internal cervical os at the time of the anomaly scan, repeat ultrasonography should be arranged in late pregnancy to exclude placenta praevia. If the placental edge is not reaching the internal os, repeat scanning in later pregnancy is unnecessary. If the placental edge is located within 2 cm of the internal cervical os (major praevia) at term, a caesarean section should be performed. When the distance is more than 2 cm (minor praevia), an attempt at vaginal delivery is appropriate but precautions should be taken to manage post-partum haemorrhage.

Screening
Chromosomal aneuploidy: Down’s syndrome accounts for about one-third of cases of severe mental disability and is the most common pattern of malformation in humans. Prenatal diagnosis currently relies on assessment of risk followed by invasive testing in those deemed to be at high risk. For many years, the basis of screening for trisomy 21 has been maternal serum biochemistry or first-trimester nuchal translucency. The traditional classification of high risk uses the highest 5% of risk for the screen-positive group. At this risk cut-off, the detection rate for trisomy 21 varies from
60% for second-trimester maternal serum biochemistry to about 70% for nuchal translucency screening.

Recent evidence suggests that maternal age can be combined with fetal nuchal translucency and maternal serum biochemistry (free β-HCG and pregnancy-associated plasma protein) at 11–14 weeks to identify about 90% of affected fetuses with a 5% screen-positive rate. Screening for chromosomal defects in the first trimester has the advantage of earlier prenatal diagnosis and consequently fewer traumatic terminations of pregnancy for couples who choose this option. A potential disadvantage is that earlier screening identifies pregnancies that are destined to miscarry, since approximately 30% of fetuses with Down’s syndrome at 12 weeks die in utero before term. All methods of antenatal screening have similar problems, however, including second-trimester maternal serum biochemistry, as about 20% of fetuses with Down’s syndrome die in utero between 16 weeks and term.

Studies from specialist centres have demonstrated that assessment of the fetal nasal bone, ductus venosus Doppler flow or tricuspid regurgitation can reduce the false-positive rate in screening for trisomy 21. However, it remains to be established whether these assessments can be made reproducibly in a routine screening setting.

Major chromosomal abnormalities are often associated with soft markers (hyperechogenic bowel, intracardiac echogenic foci, choroid plexus cysts and hydrenephrosis) that can be detected by mid-trimester ultrasound examination. The overall risk for chromosomal abnormalities increases with the total number of markers that are identified. Because of the success of first-trimester nuchal translucency screening in detecting Down’s syndrome, the subsequent detection of minor defects or soft markers later in the pregnancy is of doubtful value because the a priori risk of trisomy 21 is significantly reduced.

**Congenital heart defects:** Cardiovascular abnormalities are found in 5–10/1000 live births. Echocardiography has been applied successfully to prenatal assessment, and studies from specialist centres report the diagnosis of about 80% of moderate and severe defects in high-risk populations. The main challenge is identification of the high-risk group for subsequent referral to specialist centres. Using examination of the fetal heart (four-chamber view; Figure 4) at the time of the routine mid-trimester ultrasound scan, routine screening studies suggest a sensitivity of only 30% for the detection of major cardiac defects.

When a sibling has had a congenital heart defect, in the absence of a known genetic syndrome, the risk of recurrence is about 2%. This is equivalent to the risk in children of diabetic mothers. However, most congenital cardiac defects occur in women without any identifiable risk factors. Fetuses with increased nuchal translucency at 10–14 weeks, that are chromosomally normal, constitute a high-risk group and should be referred for specialist echocardiography. Studies suggest that the prevalence of major heart defects in this group is as high as 5%, which compares favourably with current high-risk groups.

**Neural tube defects:** Neural tube defects include anencephaly, encephalocele and spina bifida. In anencephaly, there is absence of the cranial vault (acrania) with subsequent degeneration of the exposed brain (exencephaly). Encephaloceles are cranial defects, usually occipital, with herniated fluid-filled or brain-filled cysts. In spina bifida, the neural arch, usually in the lumbosacral region, is incomplete, with secondary damage to the exposed nerves. The prevalence of neural tube defects in the UK is about 5/1000 births. Anencephaly and spina bifida account for 95% of cases and encephalocele for 5%.

These defects can be readily identified by ultrasonography. By 11 weeks of gestation, hyperechogenicity of the skull compared with the underlying tissues is normally seen. The characteristic feature of anencephaly at this gestation is acrania, with the brain showing varying degrees of distortion and disruption. When the sonographer is made aware of this, screening studies have shown that anencephaly can be reliably diagnosed at the time of the 11–14 week scan.

The diagnostic sensitivity for the prenatal ultrasonographic detection of spina bifida is about 80–90%, and the figure is even higher with prior knowledge of maternal serum α-FP results.
During the second trimester, there are well-established intracranial ultrasonographic findings that can enhance the detection of spina bifida. The ‘lemon’ sign (deformity of the frontal bone) is present in almost all cases at 16–24 post-menstrual weeks, but is less reliable after this gestation (Figure 5). Cerebellar abnormalities with obliteration of the cisterna magna are present throughout gestation in 95–100% of cases, with the ‘banana’ sign (abnormal shape of the flattened cerebellum) detectable from 15 weeks of gestation.

Encephaloceles are easily recognised as cranial defects with herniated fluid-filled or brain-filled cysts. They are most commonly found in the occipital region (75%), but may occur at other sites. Prenatal diagnosis is important as it allows the option of early termination of pregnancy for conditions that are otherwise severely debilitating. Although anencephaly is uniformly fatal, the prognosis in a fetus with an encephalocele is inversely related to the amount of herniated cerebral tissue. Overall, the neonatal mortality is about 40%, and 80% of the survivors are intellectually and neurologically handicapped. In spina bifida, intelligence may be normal, but surviving infants are often severely disabled, with lower limb paralysis and double incontinence.

Pre-eclampsia and intra-uterine growth restriction: Impaired trophoblastic invasion of the maternal spiral arteries is associated with increased risk of subsequent development of intrauterine growth restriction (IUGR), pre-eclampsia and placental abruption. As gestation advances, there is normally a decreased resistance to blood flow within the uterine arteries. If the flow velocity waveform is assessed by Doppler ultrasound, an increase in diastolic blood flow velocity is seen with a resultant fall in the resistance and pulsatility indices. In addition, the early diastolic notch in the waveform disappears. With impaired trophoblastic invasion, the high-resistance flow pattern is seen to persist until later in gestation.

Several studies in unselected populations have examined the value of Doppler assessment of the uteroplacental circulation in the prediction of pre-eclampsia and IUGR. At 20 weeks of gestation, approximately 15% of patients have a high-resistance uterine artery waveform; this figure declines to about 5% by 24 weeks. Studies of these patients in routine, unselected populations have produced conflicting results, with the prevalence of pre-eclampsia in this ‘high-resistance’ group varying from as low as 2% to as high as 24%. There are many reasons for these apparent discrepancies. Early studies were limited by the use of continuous wave Doppler, which is a blind investigation. More recent studies used colour Doppler ultrasound, which allows clear identification of the uterine artery and is therefore a more reproducible examination (Figure 6). Different population groups, gestational ages and criteria for the diagnosis of pre-eclampsia/IUGR may also account for the discrepant results.

More recent studies, using colour Doppler imaging, have suggested that up to 80% of women destined to develop severe preterm pre-eclampsia have high-resistance flow velocity waveforms in their uterine arteries at 23 weeks of gestation. Thus, using ultrasound, it may be possible to identify a small subset of the population (5–7%) that contains a high percentage of women destined to develop these severe complications of pregnancy.

Studies have shown that assessment of a woman’s level of risk of pre-eclampsia by uterine artery Doppler performs better than maternal history alone. Combination of maternal history and uterine artery Doppler findings leads to an even more accurate assessment of risk and allows the calculation of patient-specific risk. It remains to be established whether pharmacological intervention is effective in reducing the incidence of the condition in women identified to be at high risk of pre-eclampsia on the basis of Doppler examination.

Preterm delivery: Preterm labour and delivery is the major cause of perinatal morbidity and mortality in developed countries. Preterm delivery occurs in only 5–10% of pregnancies, yet more than 80% of neonatal deaths occur in pregnancies ending before 37 completed weeks of gestation and about two-thirds of neonatal deaths occur in infants delivered before 29 weeks of gestation. Advances in perinatal and neonatal medicine in recent decades have led to improved survival of preterm infants. Recent data have shown that survival rates improve from about 40–50% at 24 weeks to more than 90% by 29 weeks. Identification of women at high risk of preterm delivery at these early gestations would allow more intensive monitoring.
and the development of preventive strategies. Any such screening test would need to be sensitive and specific, with a high predictive value, to be effective in a population in which the prevalence of the condition is low. Transvaginal ultrasound has the potential to provide objective, repeatable measurements of cervical length, which may potentially be used to predict preterm labour (Figure 7).

Initial studies have assessed cervical length in high-risk pregnancies (previous preterm delivery, threatened preterm labour, multiple gestations) and have shown that the shorter the cervical length, the higher the risk of preterm labour. Using a cut-off of less than 15 mm, it is possible to identify about 2% of the population that would contain 80% of pregnancies destined to deliver before 29 weeks of gestation and 55% of those before 33 weeks of gestation. Ultrasound is a powerful screening tool for the prediction of spontaneous preterm delivery. Hormonal manipulation has shown promise in reducing the risk of preterm delivery in high-risk pregnancies, but other interventions such as antibiotics and cervical cerclage are still to show consistent results.

Reactive use of ultrasound

Fetal growth

Small for gestational age: Growth restriction may occur because of inherent fetal abnormalities or may result from substrate deprivation. However, the definition of IUGR is imprecise and somewhat arbitrary. The arbitrary identification of fetuses below the 10th or third centile as growth restricted results in the inclusion of babies that are constitutionally small but growing appropriately. This practice also fails to identify infants that have not reached their genetic potential despite being born within ‘normal’ weight criteria for a given population. Until an end point that defines abnormal growth is identified, the process of defining IUGR will remain unsatisfactory. Customised antenatal growth charts have been introduced into clinical practice in some areas which take individual variations into consideration and are designed to facilitate better supervision of fetal growth.

Growth is a functional measure of fetal condition and hence a better determinant of fetal status than pure biometry. Because of intra- and inter-observer variability, measurements should be taken at a minimum of 2-weekly intervals. The most important aspect of management is the assessment of whether an affected fetus requires premature delivery. Abnormal umbilical artery Doppler findings occur most commonly in fetuses with growth restriction due to uteroplacental insufficiency. Growth restriction in association with normal umbilical artery Doppler velocimetry (Figure 8) may indicate other aetiological possibilities such as chromosomal anomalies and congenital infection.

It is well established that delivery is indicated when there are reversed umbilical end-diastolic flow velocities after 32 weeks of gestation and absent end-diastolic flow velocities at more than 34 weeks. What remains unresolved is the optimal timing of delivery in pregnancies complicated by IUGR at 26–32 weeks. The risks of prematurity must be balanced against the risks of prolonged fetal exposure to hypoxaemia and acidemia, which may result in perinatal morbidity and mortality. Recent publications of longitudinal monitoring studies of fetal growth restriction suggested that perinatal morbidity and mortality may be improved by the use of fetal ductus venosus Doppler and fetal heart rate monitoring in optimising the timing of delivery.

Large for gestational age: Definitions of macrosomia range from birth weight greater than 4000 g to birth weight greater than 4500 g. Risks of macrosomia to the fetus include shoulder dystocia, Erb’s palsy, fractures and birth asphyxia. For the mother, prolonged labour in the first and second stage may occur, leading to greater birth canal injury and post-partum haemorrhage. Risk factors for macrosomia include established and gestational diabetes, maternal obesity, parity and prolonged gestation. Macrosomic infants of mothers with diabetes have a much higher risk of developing shoulder dystocia compared with macrosomic infants of non-diabetics.

Clinical estimation of fetal weight is unreliable, especially in the presence of maternal obesity. Fetal weight estimation by ultrasound is related to three measurements: head circumference reflecting brain size, abdominal circumference reflecting the nutritional state of the fetus, and femur length reflecting height or length. These three measurements have been combined in
various ways and used to estimate fetal weight. Unfortunately, the relative error (error as a percentage of birth weight) has been found to be 10–15%. Clinically, this means that if the estimated weight is more than 4000 g, only 77% of newborns will actually weigh more than 4000 g. This implies that the use of ultrasonographic estimated fetal weight alone is not clinically defensible, and that clinicians must realise that it has a poor positive predictive value, as all formulae tend to overestimate birth weight.

**Reduced fetal movements**

An active baby is a healthy baby. Normal fetal responses require normal fetal central nervous system function, which in turn requires adequate fetal oxygenation. Fetal tone, movements and breathing movements can all be assessed ultrasonographically. There is evidence that the various subcortical centres in the brain that control these activities have different sensitivities to oxygen, with the earliest developed being the least sensitive to hypoxia. With progressive hypoxia, breathing motions are lost first, followed by movement and then tone. Full biophysical profiles, entailing a 30-minute ultrasonographic assessment of the fetus, were popular in the early 1990s but have since fallen out of use. Cardiotocography is usually used in the presence of reduced fetal movement to reassure the clinician and parents of fetal well-being. A systematic review of randomised trials of this practice has shown no impact on perinatal mortality. Assessment of fetal growth velocity appears to be the best available test of fetal well-being in this situation, though this may have significant cost implications for clinical practice.

**Antepartum haemorrhage**

Bleeding from the vaginal tract occurring after viability and before labour has three possible causes. It may be secondary to placental separation, from a low-lying placenta, or an incidental bleed from elsewhere in the genital tract (e.g. cervix, vagina). The clinical presentation often gives a clue to the underlying cause. Apart from the exclusion of a low-lying placenta, there is no place for ultrasound in the acute management of this problem. Should recurrent vaginal bleeds occur, subsequent ultrasonography to check fetal growth can be considered.

**Ruptured membranes**

The diagnosis of ruptured membranes is usually made on the basis of a suggestive history and the demonstration of amniotic fluid volume. A study on term pregnancies would suggest that the request is made for ultrasonographic assessment of the liquor is unhelpful, as women with definite membrane rupture would be strongly supportive if the diagnosis was suspected. Once the diagnosis of membrane rupture is made, ultrasound has no predictive value for neonatal outcome, and frequent sonographic assessment is not recommended.

**Prolonged pregnancy**

The standard definition of prolonged pregnancy accepted by the WHO and FIGO is 42 completed weeks or more. Using this definition, about 4–10% of pregnancies reach this gestation. It has been recognised for many years that prolonged pregnancy is associated with increased perinatal mortality and morbidity. Different studies have shown increased intrapartum fetal death rates, increased incidence of meconium staining of the amniotic fluid, and increased fetal heart rate abnormalities in labour with a corresponding increase in intrapartum fetal blood sampling and rates of neonatal seizures. This has led to a significant increase in the number of inductions of labour in pregnancies that extend beyond the expected date of delivery.

Proponents of a conservative approach argue that, given appropriate surveillance, there should be no inherent risks in continuing with the pregnancy into the post-term period. However, there is no consensus on what constitutes ‘appropriate surveillance’. More complex fetal monitoring using a formal biophysical scoring system has been suggested, but this is arduous and trials suggest that there is no clinical benefit with this approach compared with simple monitoring. A large, population-based study from Sweden suggests that fetal size at term may be the single biggest risk factor for a poor outcome. The study showed that, at term and in the post-term period, small for gestational age babies were at significantly higher risk of stillbirth and infant death compared with appropriately sized babies. Ultrasound assessment of size may therefore aid in the determination of fetuses at risk, but further studies need to be directed in this area.

**Conclusions**

Ultrasound has largely been believed to be useful in pregnancy, providing carers with ever increasing information. Advances in technology have made it possible to image the fetus and mother in greater detail. Unless our understanding and knowledge keeps pace with technology, we are not likely to correctly use or interpret ultrasound.

**FURTHER READING**


### Practice points

- Validated roles of ultrasound in obstetrics
  - Pregnancy dating by first-trimester crown–rump length measurement
  - Nuchal translucency in Down’s syndrome screening
  - Diagnosis of fetal structural abnormality
  - Placental localisation
  - Diagnosis of multiple pregnancy and chorionicity
  - Assessment of fetal growth velocity and well-being
- Ultrasound of selected use in obstetrics
  - Cervical length assessment in screening for preterm delivery
  - Uterine Doppler assessment in screening for pre-eclampsia
- Ultrasound of limited use in obstetrics
  - Investigation of antepartum haemorrhage
  - Estimation of fetal weight at term