Antenatal detection of congenital heart disease

John Simpson

Most congenital heart defects are potentially detectable during fetal life. Detailed fetal echocardiography is indicated for high-risk pregnancies, and can now be offered at an earlier stage in gestation than was previously possible.

Congenital heart disease (CHD) is the most common type of fetal abnormality, affecting almost 1% of pregnancies (Hoffman, 1990), and is responsible for almost half of all infant deaths caused by congenital malformation. However, the detection rate of CHD during fetal life lags well behind that of virtually all other types of fetal anomaly. The aim of this article is to give an overview of this subject, focusing on specific areas:

- Current screening policies for congenital heart defects in the UK
- High-risk groups for CHD
- Types of congenital heart defect which may be identified prenatally
- Timing of fetal echocardiograms
- Management of affected pregnancies
- Influence of prenatal diagnosis on outcome.

CURRENT SCREENING POLICIES FOR CONGENITAL HEART DEFECTS

In most parts of the UK, a midtrimester anomaly scan is offered to expectant mothers. Imaging of the heart is one component of the overall assessment of the fetus. Views of the heart which are normally obtained include the 'four-chamber view' of the fetal heart as well as the aorta and pulmonary artery (*Figures 1–3*). Fetuses who deviate from the normal appearances are referred for detailed evaluation at a specialist fetal cardiology centre. At the referral centre, a fetal cardiologist performs a comprehensive examination of all connections of the heart. At virtually all tertiary paediatric cardiology centres, at least one consultant will have a specific interest in echocardiographic examination of the fetal heart.

Despite this screening policy, the last UK national data obtained between 1993 and 1995 confirmed that 75% of congenital heart defects, which required surgery or intervention in infancy, remained undetected before birth (Bull, 1999). That study also confirmed a wide

Figure 1. Normal four-chamber view of the fetal heart. This is one of the screening views obtained during obstetric anomaly scans. LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle.

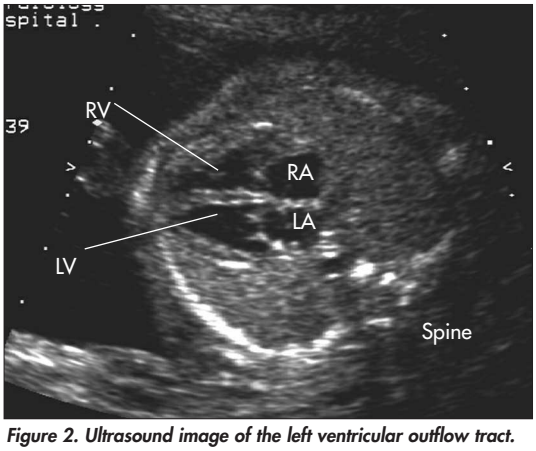
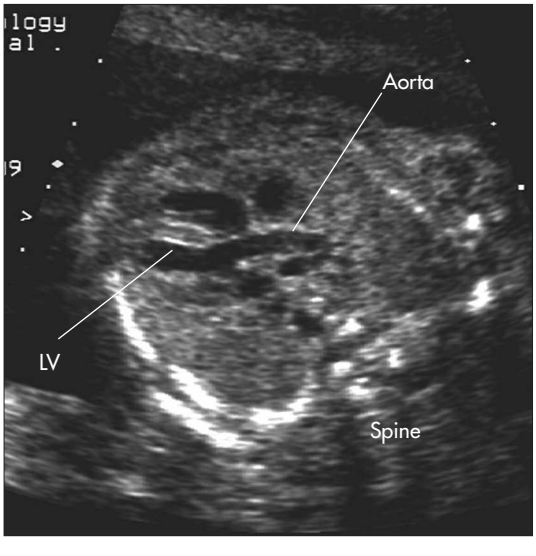


Figure 2. Ultrasound image of the left ventricular outflow tract. The aorta may be clearly seen as it exits the left ventricle (LV).



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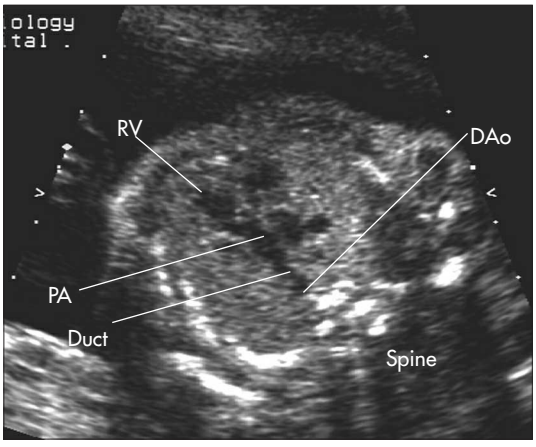

Figure 3. Ultrasound image of the pulmonary artery leaving the right ventricle. The pulmonary artery connects to the arterial duct which in turn continues into the descending aorta. DAo = descending aorta; Duct = arterial duct (ductus arteriosus); PA = pulmonary artery; RV = right ventricle.

regional variation in detection rates of CHD. In contrast to national data, single obstetric centre data confirm that some can attain detection rates of over 75% (Stumpflen et al, 1996). Therefore, although most congenital heart defects are potentially detectable before birth, the majority remain undetected in current practice. In order to improve detection rates, referral of pregnancies at high risk for congenital heart disease to specialist centres is recommended (*Table 1*).

PREGNANCIES AT HIGH RISK FOR CONGENITAL HEART DISEASE

- CHD suspected on routine obstetric anomaly scan
- Family history of CHD in a first-degree relative
- Increased nuchal translucency (NT) in the fetus
- Extracardiac malformations, e.g. exomphalos
- Maternal diabetes mellitus
- Maternal therapy with known teratogenic drugs, e.g. lithium, anticonvulsants.

TABLE 1.
Pregnancies at high risk for congenital heart disease

Such pregnancies are referred for detailed fetal echocardiography	Congenital heart disease suspected on routine obstetric anomaly scan
	History of congenital heart disease in a first-degree relative
	Increased nuchal translucency in the fetus
	Extracardiac malformations, e.g. exomphalos
	Maternal diabetes mellitus
	Maternal therapy with known teratogenic drugs, e.g. lithium, anticonvulsants

CHD suspected on routine obstetric anomaly scan

From the author's own data, if a sonographer at a referring hospital suspects CHD in the fetus, this will be confirmed in 50% of cases. The remaining 50% can be reassured of normality. Most fetuses with CHD continue to be detected in the 'low-risk' population and this group constitutes most of the fetuses with confirmed CHD.

Family history of CHD

Published data suggest an incidence of CHD of around 8 per thousand live births (Hoffman, 1990). The empiric recurrence risk of congenital heart defect is increased to 2–3% if a previous child or the father has been affected, and up to 6% if the mother herself has been affected (Allan et al, 1986; Nora and Nora, 1988; Burn et al, 1998). Increasingly single gene defects, for example chromosome 22q11 deletions, have been identified as a cause of CHD, so the recurrence risk must be tailored to the individual circumstance (Raymond et al, 1997). The involvement of clinical geneticists is important, and is mandatory where there has been a recurrence of CHD.

Increased NT

NT scans involve measurement of the fluid pad at the back of the fetal neck at 10–14 weeks' gestation. This technique was introduced primarily to screen for chromosomal abnormalities, particularly trisomy 21, but NT has been shown to have an association with CHD independent of the fetal karyotype (Hyett et al, 1999). The risk of CHD increases with increasing NT measurement. If the 95th percentile (NT 2.2–2.6 mm) is regarded as the upper limit of normal, then the sensitivity of this technique ranges from 15–56% depending on the series (Hyett et al, 1999; Mavrides et al 2001; Michailidis and Economides, 2001).

There are huge logistic implications of offering detailed cardiac scans to 5% of the pregnant population. Therefore, some have recommended detailed fetal echocardiography where the nuchal thickness is above the 99th centile (3.5 mm). The mechanism of association of congenital heart defects with increased NT is not entirely clear (Simpson and Sharland, 2000).

Extracardiac malformations

Some fetal malformations have a well-recognized association with CHD, for example, exomphalos, diaphragmatic hernia or hydrops. Such fetuses are normally referred for detailed cardiac evaluation.

Maternal diabetes mellitus
Diabetic pregnancies are at risk of fetal malformation, including CHD. In the author's series, 3% of established insulin-dependent diabetic mothers had pregnancies affected with CHD (Meyer-Wittkopf et al, 1996).

Teratogenic drugs
Mothers who are taking drugs known to be teratogenic are often referred for fetal echocardiography. Drugs such as lithium and anticonvulsant medications have a known association with CHD.

TYPES OF CONGENITAL HEART DISEASE WHICH MAY BE IDENTIFIED PRENATALLY

Detectable defects
Virtually all forms of CHD have been described during fetal life. Defects which are obvious on a four-chamber view of the fetal heart have much higher detection rates than those where extended views of the outflow tracts are required for diagnosis. For example, the reported UK national detection rate of four-chamber abnormalities such as hypoplastic left heart syndrome or atrioventricular septal defects are 66% and 38% respectively (Bull, 1999). Defects such as simple transposition of the great arteries and tetralogy of Fallot, which are compatible with a normal four-chamber view of the heart, have much lower detection rates of 3% and 10% respectively (Bull, 1999). Examples of these lesions are shown in *Figures 4* and *5*.

Defects which are difficult to detect
Some types of congenital heart defect are very difficult to detect, even in experienced hands. Such defects include small to moderate sized ventricular septal defects because the right and left ventricular pressures are equal prenatally and so shunting of blood is much less obvious than postnatally. Outflow tract obstruction such as aortic and pulmonary valve stenosis may not always be evident on a midtrimester scan and such lesions are known to progress with advancing gestational age. Coarctation of the aorta is difficult to diagnose because of patency of the arterial duct prenatally.

The presence of coarctation may be inferred by asymmetry of the size of right and left ventricles and asymmetry of the size of the great arteries coupled with relative hypoplasia of the aortic arch. However, this is not always 100% accurate and false positive and false negative diagnoses may occur. Isolated total anomalous pulmonary venous drainage may be extremely difficult to diagnose prenatally, given that pulmonary blood flow is less than postnatally. Such fetuses may show asymmetry of ventricular size as a pointer but this may not be evident until relatively late in pregnancy when few anomaly scans are performed.

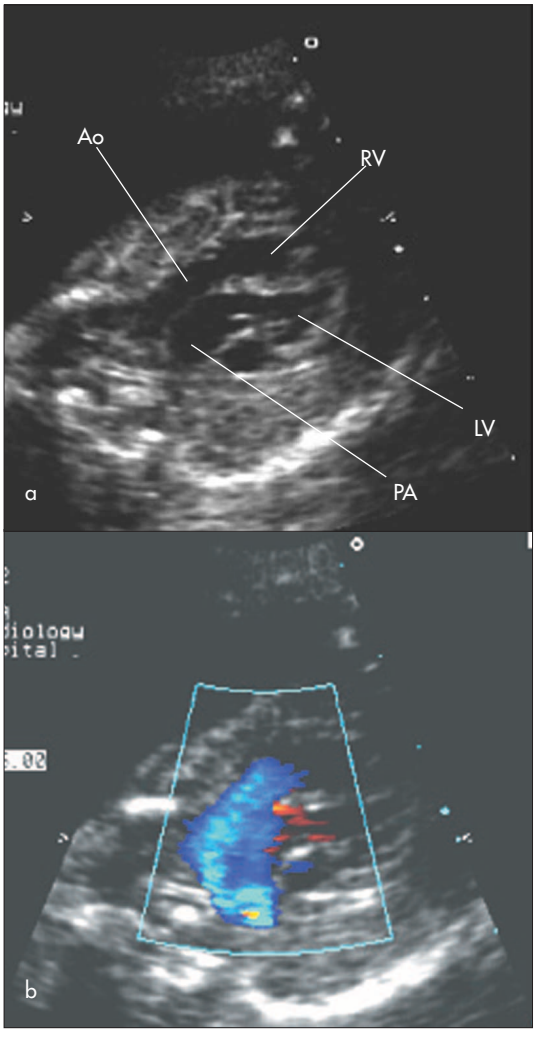

Figure 4. a. Fetal echocardiographic appearances of transposition of the great arteries. The great arteries arise in a more parallel orientation than normal. The four-chamber view is typically entirely normal explaining the relatively poor detection of this lesion during fetal life. Ao = aorta; LV = left ventricle; PA = pulmonary artery; RV = right ventricle. b. Colour flow Doppler demonstrates the flow of blood across the aortic and pulmonary valves. The orientation of the image is identical to Figure 4a.

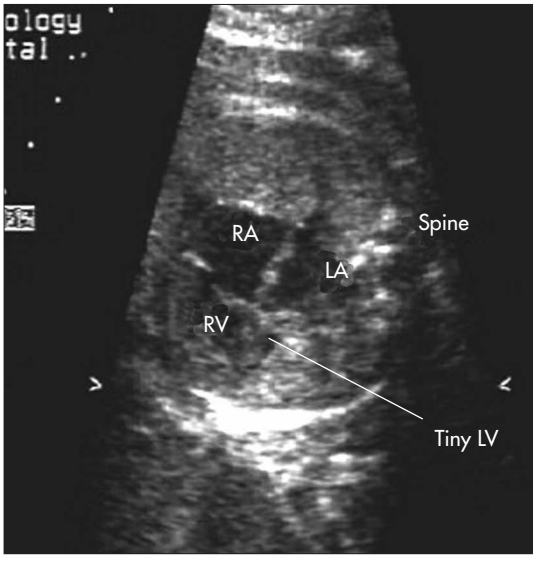

Figure 5. Hypoplastic left heart syndrome. The four-chamber view of the heart is abnormal with severe hypoplasia of the left ventricle. There is mitral and aortic atresia. LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle.

Defects which are undetectable

The arterial duct is patent prenatally. It is impossible to predict whether this will close postnatally. Secundum atrial septal defects cannot be diagnosed prenatally as virtually all fetuses have a patent foramen ovale which permits shunting of blood from right to left as part of the normal fetal circulation. It is not possible to reliably predict which of these fetuses will have a persisting interatrial communication postnatally.

TIMING OF DETAILED FETAL ECHOCARDIOGRAMS

The most usual time for detailed ultrasound examinations of the fetal heart is around 18–22 weeks of pregnancy (*Table 2*). This allows adequate visualization of all of the main cardiac connections and for most pregnancies a single thorough examination will suffice. Many referral indications, particularly where there is a family history of major CHD, or increased NT, generate a huge amount of parental anxiety and a strong desire of parents to receive as much diagnostic information as possible early in pregnancy. The increased quality of ultrasound systems has meant that it is technically possible to image the fetal heart at a far earlier stage in gestation than was previously the case.

TABLE 2.
Timing of fetal echocardiograms

Traditionally, fetal echocardiograms have been performed at 18–23 weeks, usually only a single scan is required
Detailed fetal echocardiography is possible at a much earlier stage than was previously possible (from 12–13 weeks onwards)
Early fetal echocardiograms performed in very high risk groups are repeated later in pregnancy

TABLE 3.
Management of prenatally diagnosed congenital heart disease

Detailed discussion of cardiac lesion with appropriate parental support	Discussion of treatment options and prognosis
	Option of termination of pregnancy
Investigation for associations	Detailed fetal anomaly scanning
	Offer of fetal karyotyping
Involvement of relevant professionals	Fetal medicine specialist
	Referring obstetrician
	Clinical geneticists
	Midwives/nurses
	Cardiac surgeons/interventional cardiologists
	Intensive care specialists

Transabdominal fetal echocardiography may produce adequate images from around 12–13 weeks' gestation, although images obtained around 14 weeks are typically superior to those obtained at 12 weeks. In the author's own series, diagnostic images were obtained in over 98% of pregnancies scanned at 12–15 weeks' gestation (Simpson et al, 2000). Thus, early fetal echocardiography is frequently requested, although such early scans are repeated at around 22–23 weeks to check that more subtle abnormalities have not been overlooked and that growth of cardiac structures has been normal.

MANAGEMENT OF AFFECTED PREGNANCIES

Following prenatal diagnosis of CHD, parents receive detailed information about the nature of the cardiac lesion identified (*Table 3*). There is often the need for repeated discussions at a later date because of the initial shock of the diagnosis. The natural history of the lesion is explained along with the types of procedure (surgical or interventional) which may be required, coupled with the attendant morbidity and mortality of such procedures. At the author's unit, such discussions will initially involve a consultant paediatric cardiologist and a specialist nurse or counsellor. Written information is provided along with appropriate support groups and in some cases relevant websites.

Many cardiac lesions have a strong association with chromosomal abnormalities and non-cardiac structural malformations, thus detailed anomaly scanning and the offer of fetal karyotyping is highly relevant. The nature of the cardiac lesion will have a bearing on this (Raymond et al, 1997). For example, simple transposition of the great arteries is rarely associated with karyotypic abnormalities whereas a complete atrioventricular septal defect with normal cardiac situs is very strongly associated with chromosomal abnormalities. Thus, the involvement of the referring obstetrician and fetal medicine specialist is essential. In some cases involvement of appropriate paediatric subspecialists and geneticists will be required. If pregnancy does end in termination, then parents may wish to discuss any lingering questions, discuss the results of postmortem examinations and be given an estimation of recurrence risks in future pregnancies.

For parents who elect to continue with pregnancy, the aim is to optimize postnatal care of the affected baby. This will involve a discussion of the optimal timing, site and mode of delivery. Some lesions, e.g. ventricular septal defects, rarely give rise to early neonatal problems so

delivery can take place locally and obstetric management can remain unaltered. Other conditions, e.g. transposition of the great arteries or hypoplastic left heart syndrome, may require some early intervention and so delivery at a high level neonatal centre or cardiac centre may be advised. Prior knowledge of the cardiac lesion permits a detailed discussion thus ensuring that truly informed consent is obtained. In addition, prior knowledge of babies who are due to be delivered allows rational planning of workload at the cardiac centre.

INFLUENCE OF PRENATAL DIAGNOSIS ON OUTCOME

It is not readily possible to design the perfect study which will prove the benefit or otherwise of prenatal diagnosis in terms of postnatal outcome. Heart defects which are evident on routine 20-week anomaly scans to non-specialist sonographers are typically more severe than those which are overlooked. Thus, given current screening policies it is likely that there is an ascertainment bias towards prenatal detection of more severe forms of CHD. Most data in the paediatric cardiology literature are from tertiary centres and few studies take account of mortality before reaching a tertiary centre. The data which are available suggest a significant mortality from unrecognized CHD (Abu Harb et al, 1994). In addition, some babies who are referred to cardiac centres in extremis may never be judged candidates for intervention, and so will not appear in reports of surgical or interventional cardiological procedures.

There are, however, emerging data suggesting an improved outcome for CHD diagnosed prenatally with regard to hypoplastic left heart syndrome (Tworetzky et al, 2001), coarctation of the aorta (Franklin et al, 2002) and transposition of the great arteries (Bonnet et al, 1999). Some studies have not demonstrated a benefit in terms of mortality but have shown that prenatally diagnosed infants are in a better condition before surgery (Kumar et al, 1999). HM

Conflict of interest: none.

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KEY POINTS

- Detailed fetal echocardiography should be offered for pregnancies at high risk for coronary heart disease (CHD).
- Detection rates of CHD vary according to the type of disease.
- Fetal echocardiography at specialist centres is technically feasible early in gestation.
- Affected pregnancies require a team approach for effective management.
- There is evidence of improved postnatal outcome if CHD is diagnosed prenatally.