Cardiology in the Young (2014), **24(Suppl. 2)**, 19–25
doi:10.1017/S1047951114001383

Original Article

Second trimester cardiac diagnosis: screening standards and outcomes

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Abstract Second trimester screening for congenital heart defects occurs during the routine 18–20 weeks' anomaly scan in many countries. Most congenital heart defects can be prenatally detected by experts in foetal echocardiography working in tertiary centres with high-risk pregnancies. Many studies, however, have shown that detection rates obtained by experts are not reproducible in the low-risk peripheral practices where most of the foetal screening takes place. As the majority of foetuses with congenital heart defects are born to mothers with no identifiable risk factors, it is important that widespread screening of the low-risk population occurs. To facilitate this, standard protocols have been introduced in several countries, but they are not universal and have differing sensitivities depending on the screening views advocated and the area studied. Initially, only performing the four-chamber view (basic scan) was advocated. By adding the outflow tract views (extended scan), three-vessel, and laterality views, the sensitivity of the examination can be significantly increased. Unfortunately, the sensitivity of these extended protocols still does not meet that obtainable in experienced hands, reflecting the additional skill required to obtain these extended views. Thus, close links are required between the tertiary centres and the screening centres to teach and maintain the skills required to obtain and interpret the required views, and to support the sonographer's commitment. Furthermore, an audit system is required to trace false-positive and -negative cases so that targeted interventions can be planned. This is important, as a missed case of prenatal congenital heart defect is potentially a missed opportunity to reduce postnatal morbidity and mortality.

Keywords: Foetal cardiac screening; foetal echocardiography; congenital heart disease; prenatal diagnosis; chromosomal abnormality; foetus

First published online: 27 August 2014

CONGENITAL HEART DEFECTS HAVE A REPORTED incidence of 8–10/1000 live births, making them the most common congenital malformations occurring. About a third of these congenital heart defects are severe and are responsible for significant mortality and morbidity in the neonatal period and infancy.[1–4] The idea of screening for foetal malformations began in 1980. The mainstay of current antenatal congenital heart defect detection relies on screening, usually at 20 weeks, aimed at the detection of a possible abnormality.[5] In expert hands the majority of congenital heart defects can be diagnosed prenatally by prenatal echocardiography.[4,6–8] Despite this, there has only been a moderate improvement in prenatal detection rates of congenital heart defects over the years. The figures remain disappointing and do not exceed 50% in most studies.[3–7,9–19] Screening policies are not universally implemented or uniform; many only require the acquisition of the basic four-chamber view.[19–26] In addition, the protocols are not always effectively carried out. In an effort to improve the prenatal detection

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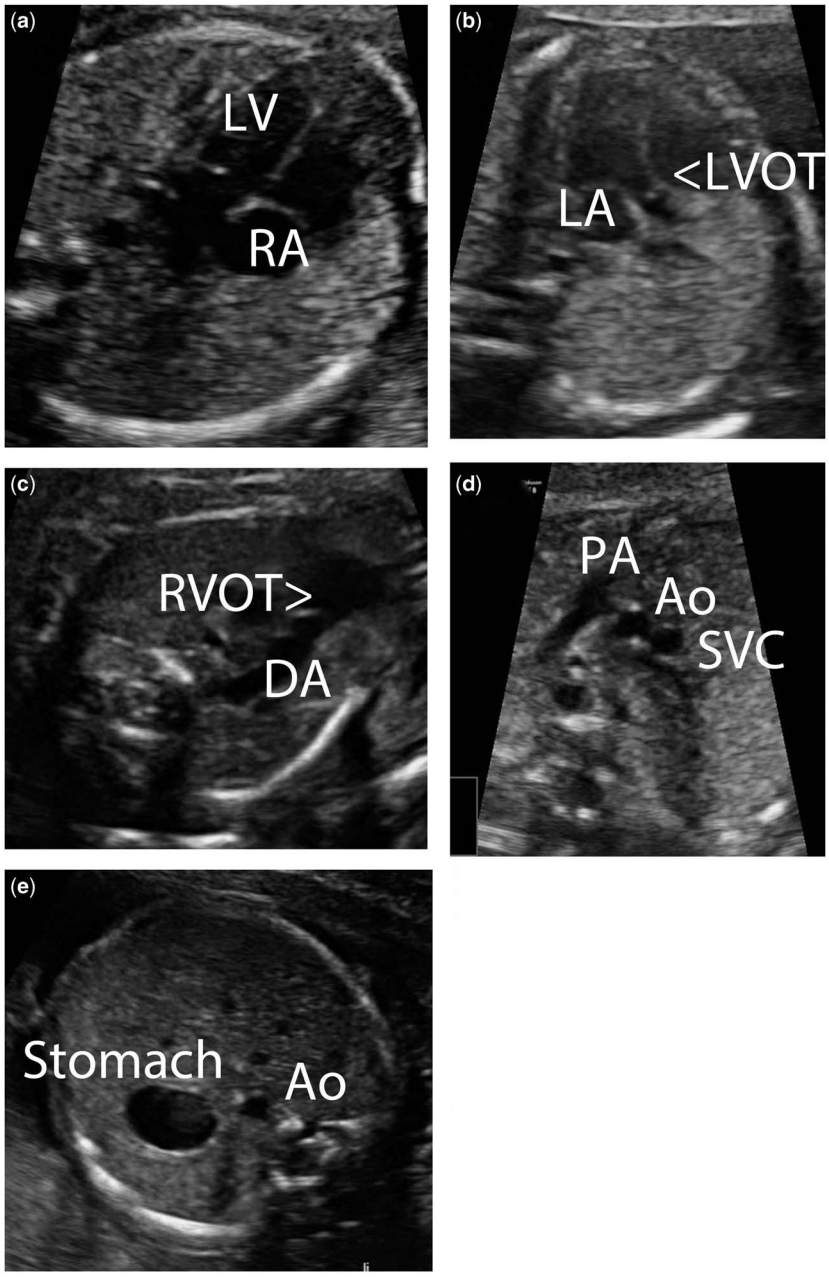

Figure 1.
*Five screening views used to evaluate the foetal heart. (**a**) The four-chamber view, (**b**) left ventricular outflow tract (LVOT) view, (**c**) right ventricular outflow tract (RVOT) view, (**d**) three-vessel view, and (**e**) laterality view. Ao = aorta; DA = arterial duct; LA = left atrium; LV = left ventricle; PA = pulmonary artery; RA = right atrium; SVC = superior vena cava.*

of congenital heart defects, a nationwide policy for 2010 has been proposed in the United Kingdom,[27] recommending the inclusion of several views of the foetal heart during 20 weeks' gestation anomaly scan (Fig 1). This is important, as a missed case of prenatal congenital heart defect is a missed opportunity for further diagnostic procedures, counselling, monitoring, and implementation of patient-tailored (intrauterine, perinatal, and postnatal) management, and is potentially a missed chance to reduce postnatal morbidity and mortality.[28–35]

Factors associated with low detection rates

A moderate improvement in the detection rates of congenital heart defect screening has been seen worldwide over the past 30 years; however, there is much area variability and the figures remain disappointing.[9,12,18,19,35–41] The assessment of the heart appears to be the most difficult aspect of the 20-week ultrasound examination, possibly because of its rapid movement and the influence of foetal position.[5]

https://doi.org/10.1017/S1047951114001383 Published online by Cambridge University Press

This is supported by the findings of lower congenital heart defect detection rates compared with that of other malformations in many studies.[15,16]

Availability is important for a successful screening programme. More than 90% of the mothers undergo a foetal ultrasound in most countries.[12,40] Although widely practiced, a routine antenatal ultrasound was not yet included in the standard care of a pregnant woman in the United States of America in 2003,[42] and a screening ultrasound has only been universally available in the Netherlands since 2007. Failure to undergo a screening ultrasound has been associated with delayed prenatal care, higher parity, and residence in a low-income area, whereas some studies have not found socio-economic status to be a factor.[12,40] Gestational age, maternal body habitus, previous maternal abdominal surgery, position of the foetus, amniotic fluid volume, ultrasound machine used, and technical difficulty in obtaining the views may all influence the ability to conduct an adequate screening study.[12,37,40,42–44]

The location where the ultrasound in performed significantly affects its sensitivity. Better detection rates are found in high- versus low-risk clinics and in university centres versus community practices.[12,40,41,44–46] The ultrasound operator and reader's experience and motivation are important factors.[11,40,41,47] A referral for specialised foetal echocardiography should follow all abnormal screening test findings, which, unfortunately, only occurred in 42% of cases in one study.[40] Even then, 3% of the congenital heart defect diagnoses were missed. These were predominantly cases of coarctation of the aorta.[40]

Presently, specialised foetal echocardiography is reserved for high-risk pregnancies. Of the many risk factors for congenital heart defects, including family history, maternal metabolic disease, teratogen exposure, known aneuploidy, other foetal abnormalities, foetal arrhythmia, maternal systemic lupus erythematosus, and increased nuchal translucency, the risk factor most predictive of a congenital heart defect is an abnormal cardiac assessment at routine ultrasound.[38,42,48] Most cases of congenital heart defects are found in mothers without risk factors.[48–51] Thus, to be effective, universal rather than targeted screening should be adopted.[42,49,52]

Interestingly, the detection rates are better if there is a family history of a congenital heart defect, or if there are associated extracardiac anomalies, presumably because the heart is examined more thoroughly and because a referral to a tertiary centre is more likely.[40] Failure to diagnose a congenital heart defect prenatally leads to significantly higher ventilation rates and more usage of prostaglandins as they are often started, sometimes unnecessarily, when a baby with a suspected congenital heart defect is transferred from the periphery to a tertiary centre.[12]

Screening views used in standard protocols

The four-chamber view

The idea of evaluating the heart by looking at one slice, the four-chamber view, was introduced in 1985 and was shown to be successful in the hands of the routine sonographer.[17] Initial reports of the screening efficacy of the four-chamber view were very promising, with a reported sensitivity of 80–87% in early studies.[53,54] However, later studies have failed to reproduce these high figures.[15,47,55] Unfortunately, this view is still not correctly evaluated in all 20 weeks of screening ultrasound examinations and has a reported sensitivity of 30–50%.[15,17,37,45,47,55]

The most frequently detected congenital heart defects are those that are best seen on the four-chamber view and are thus those that affect the cardiac chambers and atrio-ventricular valves such as single ventricle, atrio-ventricular septal defect, hypoplastic left or right heart syndrome, and Ebstein's anomaly.[12,15,36,37,41,42,44,49,56] Conotruncal lesions are often missed as they have, or may appear to have, a normal four-chamber view in as many as 70% of cases.[12,17,57] Examples include transposition of the great arteries, tetralogy of Fallot, truncus arteriosus, and double outlet right ventricle.[42,58,59] Left ventricular outflow tract abnormalities will also often be missed if only the four-chamber view is evaluated. Owing to the thin appearance of the superior aspect of the interventricular septum, especially on the apical four-chamber view, subaortic ventricular septal defects can be overdiagnosed.[44] Ventricular hypoplasia, cardiomyopathies, and cardiac tumors may develop as the pregnancy progresses and only become apparent later, and pulmonary and aortic stenosis may be difficult to detect at 20 weeks' gestation.[60]

Of course, certain diagnoses cannot be made prenatally, such as the patent arterial duct and secundum atrial septal defect. The diagnosis of aortic coarctation remains very difficult with high false-positive and -negative rates even in experienced hands.[8,40,61,62] This is because it is a lesion that develops postnatally when the arterial duct closes and the prenatal indicators are non-specific. A small ventricular septal defect may easily be missed; however, with the current improved technology, there appears to be an epidemic of prenatally diagnosed haemodynamically insignificant ventricular septal defects, potentially leading to unnecessary parental distress if not correctly counselled.

Outflow tract view

Some defects commonly missed in the four-chamber view, such as transposition of the great arteries[63] and left ventricular outflow tract obstruction,[46] have a very short presymptomatic period and may require urgent intervention postnatally, especially if the patient's survival is dependent on arterial duct or oval fossa patency.

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Affected foetuses are better delivered in centres with immediate access to treatment. Studies have shown that prenatal detection improves the outcome,[28–35] and therefore strategies for increasing the detection of outflow tract abnormalities could improve the outcome of these babies.[62] This is the rationale behind the "extended view" screening protocols.

Initially, investigators suggested the inclusion of the five-chamber view or left ventricular outflow tract view, and later the addition of the right ventricular outflow tract view was advocated for a complete study.[42,50,64] Overall, detection rates can be increased from 40 to 50% using the four-chamber view alone to 75–90%, with the inclusion of the outflow tract views;[7,39,49,50,56,58,64–66] however, unfortunately, implementation of the extended protocol is still far from universal. Studies looking at the sensitivity of the outflow tract view in screening studies have also shown suboptimal detection rates in the order of 57–65%.[10,12,38,40] The major risk factor for a missed congenital heart defect is the failure to detect the congenital heart defect at the screening ultrasound, particularly for defects expected to have only or mainly an abnormal outflow tract view.[40] In a recent study, 42% of the congenital heart defect cases with an expected abnormal four-chamber view, 64% with an expected abnormal outflow tract view, and 30% with both views expected to be abnormal were missed prenatally.[40] The detection of congenital heart defects, especially when using the outflow tract view, depends on the skill of the operator required to visualise the outflow tracts as well as the experience required to correctly interpret the anatomy.[11,12,40,47,67] The sonographer should have access to up-to-date technology, have a high index of suspicion for a cardiac abnormality, and have a structured, methodical approach to the foetal heart screening examination.[42] Furthermore, the sonographer has to have the ability to interpret the images obtained to recognise the normal from the abnormal views.[11,12,40]

The three-vessel view

Both the three-vessel view and three-vessel and trachea view have been reported to be efficient in identifying several congenital heart defects.[59,68–71] A recent report prospectively assessed the use of an integration of both views in the prenatal detection of congenital heart defects and found an overall sensitivity of 71% – 89% when ventricular septal defects were excluded – and a 100% sensitivity in the case of transposition of the great arteries, common arterial trunk, aorta and pulmonary stenosis, and ductal aneurysm. Most cases of double outlet right ventricle, Ebstein's anomaly, tricuspid atresia, and two of three cases of tetralogy of Fallot were identified. Factors that were considered in the evaluation of the three-vessel view included: vessel size, alignment, arrangement, number, sidedness, and direction of flow.[71] To improve the prenatal detection rate of congenital heart defects, the addition of the three-vessel view to the extended routine screening protocol has been proposed.[68,69] The views are easy to teach and learn as their sonologic planes are orthogonal to the foetal body long axis, and can be easily obtained by tilting the transducer a little cranially from the four-chamber view.[71] In a study on 8025 foetuses, the four-chamber view alone was found to have a sensitivity of 66%. The addition of the three-vessel view improved the sensitivity to 81%.[59]

Standardisation of screening

Screening policies are unfortunately not universally implemented or uniform. Despite the definite benefit obtained by the addition of extended screening views, consensus statements of many professional bodies only recommend the performance of the four-chamber view and, "if technically feasible", the outflow tract view.[20–26] In Canada, the outflow tract view is now recommended,[72] and in the Netherlands (2007) the four-chamber view, outflow tract view, and the three-vessel view are included.[73] In the United Kingdom, the Fetal Anomaly Screening Program advocates including the laterality view, four-chamber view and outflow tract views to improve the standards of practice in the future. Colour Doppler is as yet not required.[27] Advanced training with regular updates is required to maintain the skill required to obtain the extended views and this may explain why many screening programmes are still limited to just a four-chamber view.[15,38,58,65]

Future directions

Automated screening

Improvements in image acquisition and analysis will result in more complete diagnosis of malformations in all systems of the foetus at the screening level.[35,41] The advent of 3D and 4D ultrasound has revolutionised the detection of foetal abnormalities. With the advent of spatiotemporal image correlation described by DeVore et al,[74] cardiac volumes can be obtained in 95% of cases in specialist centres, with 70–90% adequate visualisation of the heart. The two ways in which spatiotemporal image correlation can improve congenital heart defect detection rates are acquisition of cardiac volumes locally at the screening centre, with subsequent analysis by an expert foetal echocardiographer at a remote site; and storage and analysis of the volumes by the examiner at a later time.[67,74,75] Sonographers need to be able to acquire clinically valid cardiac data sets and to discard

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suboptimal ones and the reviewer must be able to detect the cardiac abnormalities.[67] Using the spatiotemporal image correlation technology, a single volume is acquired from the apical four-chamber view, which all screening sonographers should be able to obtain. This then removes the need for manual insonation of the outflow tract, making it a potential option for screening in the future.[67] However, to obtain an optimal spatiotemporal image correlation can be challenging owing to the dependence on foetal position and foetal immobility.

Colour Doppler

As yet, colour Doppler has not been systematically included into screening protocols, but there is an intention in the United Kingdom to introduce it in the future.[27] With colour Doppler, abnormal flow can be identified allowing for better detection of ventricular septal defects and ductally dependent lesions.

Serum markers

The use of second trimester serum markers to augment the ultrasound screening for congenital heart defects has been considered.[76]

Increased nuchal translucency and earlier scans

The measurement of the nuchal translucency at 11–14 weeks is being proposed for the screening of all pregnancies.[77] Studies have shown that the risk for congenital heart defects increases with increasing nuchal translucency measurement, especially when associated with tricuspid regurgitation and an abnormal ductus venosus Doppler.[77–81] This has led to a call for earlier screening ultrasounds, at 14–18 weeks, in selected cases after the nuchal translucency measurement (e.g. nuchal translucency $\geqslant$3 mm).[79,82] This would allow earlier diagnosis and decision making, or reassurance, depending on the findings, but requires simple guidelines to ensure uniformity of care, adequate local resources, and skilled personnel.[79,82,83]

Conclusions

A missed case of prenatal congenital heart defect is potentially a missed opportunity to reduce postnatal morbidity and mortality.[28–35] Unfortunately, despite a high uptake of foetal screening, the detection rates for congenital heart defect remain low. Screening programmes implemented and described so far depend heavily on the ultrasound views used and the experience of the professionals performing and reading the scans.[11] The sensitivity is the lowest when the screening is performed by an inexperienced sonographer, using an outdated ultrasound equipment, in the absence of an associated extracardiac abnormality, in low-risk community practices, in the absence of a family history of congenital heart defect, and in lesions with only or mainly an abnormal outflow tract view or abnormal three-vessel view.[40] Detection rates using only the four-chamber view are much lower than those achieved using an extended screening procedure (four-chamber view with outflow tract views or three-vessel view).[38–40,59]

Screening protocols should be standardised to include at least the four-chamber view and outflow tract view, and the three-vessel view if possible.[27,72,73] Close links are required between the tertiary centres and the screening centres to teach and maintain the skills required to obtain and interpret the required views.[12,52] An audit system tracing false-positive and -negative cases can assist targeted interventions (training) to improve the skills of those performing and reading the scans. Regular refresher courses are also essential to keep the skills updated.[52]

Conflicts of Interest

We have no conflicts of interest to declare.

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