Single centre audit of early impact of inclusion of the three vessel and trachea view in obstetric screening

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Abstract

Detection rates of congenital cardiac malformations have traditionally remained low. The NHS Fetal Anomaly Screening Programme (FASP) aims to increase these detection rates for various reasons, including influencing perinatal management and aiding parental decision making. The inclusion of the three vessel view and trachea (3VT) view in 2015 aimed to improve detection rates of arch abnormalities in particular. This study evaluated the early impact of the new initiative at one NHS Trust. Departmental screen-positive rates were compared for a full year before and after implementation. Referrals to, and opinions of, the foetal medicine unit (FMU) were assessed; as were undetected congenital heart defects for the two time periods. Compared with the pre-implementation (pre-3VT) period, the number of completed anomaly scans performed after implementation (post-3VT) increased by 3% and the number of FMU referrals increased by 625%. Departmental screen-positive rates for cardiac abnormalities increased from 40% (pre-3VT) to 91% (post-3VT). Over half (52%) of the FMU referrals were made due to a suspected abnormal 3VT view. Early evaluation of 3VT implementation at this NHS Trust indicates that it has been a success. Departmental screen-positive rates for congenital cardiac malformations have risen. However, this performance has come at a cost: Some abnormalities now being detected, such as loose vascular ring and PLSVC, are frequently asymptomatic and likely to be clinically insignificant. The implementation of 3VT achieves the aims of FASP but may begin to exceed what is expected from a low risk population screening programme.

Keywords

3VT, FASP scanning, CHD, ultrasound scan, obstetrics

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Introduction

Congenital cardiac malformations occur frequently. Prevalence varies around the world but is approximately 8 per 1000 births.^{1,2} Prenatal detection rates for congenital heart disease (CHD) using ultrasound have traditionally remained low but in recent years have started to improve.² The majority of malformations occur in a low risk population³. Prenatal detection may influence the outcome of the pregnancy by assisting parental decision-making at the time, which may include genetic testing since some cardiac abnormalities have strong associations with syndromes such as Down, Turner and DiGeorge.⁴ Prenatal detection can

also aid perinatal management since neonates with certain types of cardiac abnormalities show improved outcome by benefitting from planned delivery and surgical intervention at a specialist centre.⁵ Therefore, it is of value to maximise detection rates at the prenatal anomaly ultrasound scan.

Before 2000, the antenatal ultrasound detection rate for cardiac malformations at routine second trimester examinations was around just 17%.⁶ These cardiac

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abnormalities were classified as having associations with possible immediate or short-term morbidity. By 2003, almost a quarter were diagnosed prenatally and by 2011/2012 the figure had risen to 35%.⁷ Over 40% of cases were being detected in England by 2013² but this figure still fell short of the 50% target sought by the NHS Fetal Anomaly Screening Programme (FASP).⁸

Multiple training and education initiatives to help sonographers detect more cardiac anomalies during ultrasound screening have been designed by FASP, including the introduction of more robust guidelines in 2010. These guidelines stated explicitly that assessment of the cardiac great vessels was to be included in the 18⁺⁰ to 20⁺⁶ weeks anomaly scan and recommended that the appointment time for each woman should be 30 minutes.⁸ FASP has offered clinical departments free visits from fetal cardiologists or specialists from the Tiny Tickers charity, which is concerned with improving detection of, and caring for babies with, CHD.⁷ FASP also provides free online e-learning sessions, which our Trust's sonographers have undertaken.

Perhaps as a consequence of these initiatives, and arguably as image resolution has improved, cardiac anomaly detection rates have gradually and steadily increased. To encourage further improvement, in 2013 a working party organised by FASP opted to recommend that assessment of the 'three vessel and trachea' (3VT) view (Figure 1(a) to (c)) be included as standard into the anomaly scan in addition to the cardiac chambers and great vessel views already recommended. It was anticipated that inclusion of the 3VT view would help detect cardiac arch abnormalities, which frequently have a normal four chamber configuration and are therefore often undetected. It was also anticipated that it would help with identifying four serious cardiac conditions: transposition of the great vessels, hypoplastic left heart, Fallot's tetralogy and atrioventricular septal defect (AVSD).⁹

Training of staff to assess the 3VT would begin in 2015 with full implementation of the view in all NHS departments in England expected by December 2016. FASP updated its guidelines in 2015 to incorporate this change.¹⁰

Figure 1. Normal three vessel and trachea appearance in B-mode (a), with colour Doppler showing correct blood flow direction (b) and as a schematic diagram (c). Note: 1: Trachea; 2: SVC; 3: Aorta; 4: Pulmonary artery; 5: Ductus arteriosus; 6: Spine.

Our department participated in the training by sending an experienced sonographer to a FASP two-day workshop, which comprised theoretical and practical elements. Over the following weeks the sonographer then ‘cascaded’ training in-house to all our obstetric sonographers via a mix of a short presentation, an information leaflet and one-to-one practical support during routine anomaly scans. We have included the 3VT as part of our routine foetal heart assessment during the anomaly scan since March 2016. To investigate any early positive or negative impact from this new initiative, we compared our detection rates for foetal cardiac abnormalities for a full year before training began and for a full year after implementation of the 3VT view.

Method

The radiology information system (RIS) statistical package was used for initial data gathering. The pre-implementation (pre-3VT) period for audit was 1 March 2014 to 28 February 2015. The post-implementation (post-3VT) period was 1 March 2016 to 28 February 2017. The total number of completed 20 week scans was found for each specified time frame.

Data gathering was split into two areas; referrals to the foetal medicine unit (FMU) and undetected congenital abnormalities from newborn screening records. All local FMU referrals were collated for the specific time frames. These referrals were found via a shortcode used on the sonographer-generated RIS reports. If a sonographer suspected an abnormality that required a foetal medicine review the following phrase was included in the report:

‘Suspected fetal anomaly has been discussed and referral to fetal medicine has been arranged’.

Thus, it was possible to collate all FMU referrals from RIS. However, the referrals were then cross-matched with all referrals received by the FMU; in this way any referrals that were not documented on the RIS (i.e. if the shortcode was not used) were not missed. The matching referrals were categorised into cardiac and non-cardiac conditions. Patient notes were then assessed to ascertain the FMU scan outcome of cardiac referrals.

The screen undetected congenital abnormalities were found by accessing the hospital database for newborn congenital abnormalities. This database included all babies with abnormalities found at ‘newborn checks’. The time frames used for this search was 29 March 2014 to 1 August 2015 for the pre-3VT period, and 29 March 2016 to 1 August 2017 (post-3VT). These dates equate to deliveries from 24 to 42 weeks in the given time frames. The list was then scrutinised for undetected cardiac abnormalities only.

The local Emergency Department was also contacted to determine whether any infants were brought in by ambulance with potential undetected cardiac abnormalities.

Results

Pre-3VT period

In total, 5284 anomaly scans were completed in the pre-3VT period. Four suspected cardiac abnormalities were referred to the local FMU. One of the four referrals was found to be normal. One referral outcome was unknown. Two cardiac abnormalities, Fallot’s tetralogy and common arterial trunk, were correctly referred to FMU.

Three cardiac abnormalities: an atrioventricular septal defect, a valve malformation and a pulmonary valve stenosis were undetected during the pre-3VT period.

The referral with the unknown outcome is excluded from our figures. Therefore, based on two detected cases and three undetected cases in total, this suggests a 40% departmental screen positive rate for the year before 3VT views were included in screening.

Post-3VT period

The total number of completed anomaly scans in the post-3VT period was 5445 (an increase of 3% from the pre-3VT period). The number of suspected cardiac abnormalities referred to the local FMU increased from four in the pre-3VT period to 29 in the post-3VT period – an increase in referral rate by sonographers of 625% (Table 1).

Table 1. Number of scans performed and referrals made to the local foetal medicine unit (FMU)

	Pre-3VT period (frequency)	Post-3VT period (frequency)
Total anomaly scans performed	5284	5445
Cardiac referrals to FMU	4	29
Confirmed abnormalities by FMU	2	21
False positive referrals (i.e. found to be normal)	1	8
Unknown (lost to follow-up)	1	—
Screen undetected	3	2

Table 2. Screen undetected congenital cardiac abnormalities from newborn database

Type of abnormality	Pre-3VT period (frequency)	Post-3VT period (frequency)
Pulmonary valve stenosis	1	—
Pulmonary artery stenosis	—	1
Congenital malformation of valves	1	—
Atrioventricular septal defect (Trisomy 21)	1	—
Atrial septal defect	—	1
Total	3	2

Of the 29 referrals to FMU, 8 were deemed normal. The screen false positive rate for sonographers therefore increased slightly; from 25% (1 out of 4 incorrect referrals) in the pre-3VT period to 28% (8 out of 29 incorrect referrals) in the post-3VT period.

A total of 21 cardiac abnormalities were correctly referred to FMU. All outcomes are known. Two cardiac abnormalities, pulmonary artery stenosis and an atrial septal defect (Table 2), were undetected during the post-3VT period. Therefore, based on 21 detected cases and 2 undetected cases, this suggests a departmental screen positive rate of 91%.

The type of abnormalities confirmed by FMU, for both the pre- and post-3VT periods, are listed in Table 3. Out of the 29 referrals made to FMU, more than half (51.7%, $n = 15$) were made as a direct result of the sonographer suspecting an abnormal 3VT configuration. Table 4 shows the subsequent FMU diagnosis for those 15 referrals. Four of the suspected abnormal 3VT views were found to be normal. Two were common variants; a persistent left superior vena cava (PLSVC), which occurs when the left anterior cardinal vein fails to regress during foetal development (Figure 2(a) and (b)), and four were aortic arch abnormalities described by our FMU specialists as vascular ring malformations; these involve an anomalous configuration of the arch and associated vessels, which partially or totally encircle the trachea and/or oesophagus (Figure 3(a) and (b)).

Discussion

Our data set reveals some surprising findings. At only five in the year before training began, and 23 in the year

Table 3. Types of cardiac abnormalities confirmed by the local foetal medicine unit

Type of abnormality	Pre-3VT period (frequency)	Post-3VT period (frequency)
Tetralogy of Fallot	1	4
Common arterial trunk	1	1
Loose vascular ring	—	4
Persistent left superior vena cava	—	2
Hypoplastic left heart	—	3
Pulmonary atresia	—	1
Pulmonary valve stenosis	—	1
Transposition of great arteries	—	2
Double inlet left ventricle	—	1
Coarctation of aorta	—	1
Atrioventricular septal defect	—	1
Total	2	21

Table 4. Foetal medicine unit diagnosis for our referrals specifically for suspected abnormal 3VT view

FMU diagnosis for suspected abnormal 3VT view	Frequency
Normal	4
Loose vascular ring	4
Persistent left superior vena cava	2
Tetralogy of Fallot	2
Pulmonary valve stenosis	1
Coarctation of aorta	1
Hypoplastic left heart	1
Total	15

Figure 2. An example of a persistent left superior vena cava (a). Note the additional vessel to the left of the pulmonary bifurcation. The same example as a schematic diagram (b). Note: 1: Pulmonary artery; 2: Aorta; 3: Trachea; 4: Persistent left superior vena cava.

Figure 3. An example of a loose vascular ring showing the trachea within the 'U' shaped vascular configuration rather than to the right of the aortic arch (a) and as a schematic diagram (b). Note: 1: Pulmonary artery; 2: Trachea; 3: Superior vena cava; 4: Aorta; 5: Ossification point of spine.

after, there is a large discrepancy between the frequency of cases of CHD, both detected and undetected, at our Trust. It would have been reasonable to expect the total number of cases to be higher in both years. With a birth rate of over 5000, around 40 cases per year could be anticipated although not all will be eligible for detection using prenatal ultrasound in that the initial presentation of some conditions is only after birth. Arrhythmias, cardiomyopathies and some structural conditions such as patent ductus are all examples of CHD that may not be detectable ultrasonically in the second trimester.

It may be that our annual rate of cardiac abnormalities varies considerably between years but only by retrospectively analysing data from a number of consecutive years would we be able to confirm or refute this. To our knowledge, we have not missed inclusion of any known newborn CHD, although it is possible some were not reported to our Women and Children's Services and have been lost to follow-up after tertiary referral. Additionally, some infants born towards the end of the data collection period are still less than a year old and may yet have an undiagnosed cardiac problem.

Our data suggest implementation of the 3VT view at our Trust has been a success. Results in the year after training indicate that more heart malformations in general, not just arch abnormalities, have been detected. The reason for this is unknown but anecdotally staff reported that, as a consequence of 3VT training, they felt more confident in evaluating the heart as a whole and felt their evaluation of great vessels had also improved. This notion is supported by the fact that two of the conditions not identified in the year before training, namely pulmonary valve stenosis and an atrio-ventricular septal defect, were subsequently detected after training, although it is likely that other factors may have played a part too.

It is also of significance that transposition of the great arteries was detected on two occasions after training. Traditionally, low prenatal detection rates are associated with this condition and studies have cited figures as low as 6% in the 1990s¹¹ and still just 17% this decade.¹² However, in more recent years, a detection rate of 41% has been reported,¹¹ while in 2017 a Canadian team claimed a rise from 14% to 77% in just 5 years and attributed this success to improvements in guidelines supporting screening sonographers.¹³ Based on our results, a similar situation, as a consequence of FASP's continued efforts, may now start to emerge in England.

When considering the four major CHDs on which FASP has focused in 2015, after 3VT training we detected four cases of Fallot's tetralogy, three hypoplastic left hearts, one AVSD and two cases of transposition of the great vessels. To our knowledge none went undetected and the training most likely had influence.

Although the number of total cases were low, our departmental screen positive rate for CHD in the year before 3VT training was 40%. The antenatal detection rate for CHD across regions in England is variable but ranges between 20% and 50%.¹⁴ In the year after training, 21 cases out of 23 were identified, which suggests a departmental screen positive rate of 91%, although it is acknowledged that not all 23 cases could be classed as 'serious cardiac anomalies', a phrase used by FASP in its handbook when offering guidance on CHDs that warrant detection.¹⁰ Nevertheless, some mild malformations and variants such as isolated arch abnormalities and PLSVC are associated with syndromes and therefore their detection may prompt chromosomal analysis to be considered although this remains a controversial area.¹⁵

That our departmental screen positive rate is higher in the year after inclusion of the 3VT view is to be expected since some conditions, such as persistent left superior vena cava (PLSVC) and isolated vascular ring

malformation, would likely have gone undetected prenatally previously and indeed may remain asymptomatic in the individual.

Four cases of vascular ring malformation were diagnosed prenatally and their detection can be attributed directly to successful incorporation of the 3VT view. The term 'vascular ring malformation' covers a spectrum of arch abnormalities concerning the position of the trachea in relation to the aortic arch and ductus arteriosus. Many examples comprise a right aortic arch and some involve a double aorta. All are usually a consequence of abnormal positioning of the aortic arch or abnormal branching due to inadequate regression of structures during early embryology.¹⁵ Ultrasound appearances are of a partial or complete vascular ring encircling the trachea (Figure 3(a) and (b) show an incomplete ring) or oesophagus. While most are asymptomatic some, such as double aortic arch, may cause tracheal compression postnatally.¹⁵ Aortic arch abnormalities are not rare and occur in up to 2% of the population. Around half are associated with CHD. Most aortic arch anomalies are clinically unimportant but they are associated with chromosomal defects such as 22q11 microdeletion (DiGeorge syndrome).¹⁵ The four cases at our Trust all received a good prognosis, proceeded to term and had no known post-delivery complications. Genetic testing was offered to three and of these, two declined and one underwent amniocentesis, which revealed a normal karyotype.

There were two diagnoses of PLSVC (Figure 2(a) and (b)) which, in isolation, has an excellent prognosis and is considered a normal variant by some.³ However, as with arch anomalies and vascular rings, chromosomal anomalies are associated with PLSVC as well as coarctation of the aorta.¹⁶ Only a neonatal echocardiogram was recommended for our two cases since the PLSVC was isolated.

As staff become increasingly adept at recognising subtle arch abnormalities and minor variants previously identified only by foetal medicine specialists, the number of referrals from screening centres like ours may continue to rise. The FASP guidance states the ultrasound screening programme should aim to detect at least 50% of serious cardiac anomalies. It is difficult to see how isolated vascular ring malformations and PLSVC fit into this category. Further data analysis from subsequent years may help to establish the value of our increased detection of such conditions.

In the meantime, during this transition period, we encourage second opinions from other staff members before tertiary referral but have no wish to discourage staff from referring to FMU when in doubt. Notably, NHS England anticipated an increase in referrals to foetal medicine, foetal cardiology, counselling and

psychological support when it was planning improvements in antenatal ultrasound standards in 2015.¹⁴ The emotional impact on women offered a tertiary referral must not be underestimated but, at the same time, women opting for ultrasound screening must be aware that all screening programmes generate uncertainties and false positives.

Despite our apparent high detection rate for eligible heart conditions during our sample year after 3VT implementation, it is inevitable that some cases of serious CHD will continue to remain undetected at the anomaly scan. Reasons for this are multifactorial and well known but include maternal obesity, foetal lie, uterine fibroids, false negatives leading to misinterpretation as 'normal' and ineligible heart conditions such as some murmurs and cardiomyopathies, and patent foramen ovale and patent ductus arteriosus. Currently, FASP recommends an additional final anomaly scan to be attempted by 23 weeks' gestation.¹⁰ If anatomical areas remain unseen, these must be recorded in the patients' notes but no further anomaly scans should be booked. Although our department has seen a marked improvement in identifying CHD, it is essential to continue to monitor performance, support education and training, and provide feedback to staff on anomalies both detected and undetected as they come to light. We recommend further similar studies at other NHS Trusts so that experiences may be compared. National figures on the direct impact of inclusion of the 3VT view routinely will be available, no doubt, in due course.

Conclusion

Our study, based on data from two separate years, has revealed a lower than expected prevalence of CHD. However, the results are complete and encouraging. Early analysis of implementation of the 3VT view indicates that it has contributed to improving CHD prenatal detection rates, therefore it must be viewed as a success. Currently, our departmental screen positive rate suggests a figure of 91%, which exceeds national average detection rates and the target recommended by FASP. However, this performance has come at a cost: Some abnormalities now being detected, such as vascular ring malformation and PLSVC, are frequently asymptomatic and likely to be clinically insignificant. From our initial analysis, it may be that the introduction of the 3VT view achieves the aims of FASP by increasing antenatal detection of major CHDs but begins to exceed what is expected from a low risk population screening programme. Frequent identification of common variants and mild malformations will add to the workload of foetal medicine specialists and will likely lead to more women being offered counselling and foetal karyotyping.

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Ethics approval

The hospital Research and Development team was contacted and informed of our intention but stated that ethical approval for this service evaluation was not required.

Guarantor

HE.

Contributors

HE researched literature and conceived the study. RH and HE designed the audit. RH performed the data analysis. HE wrote the first draft of the manuscript. RH and HE wrote the final version of the manuscript. All authors reviewed and approved the final version of the manuscript.

References

1. van der Linde D, Konings EE, Slager MA, et al. Birth prevalence of congenital heart disease worldwide: a systematic review and meta-analysis. *J Am Coll Cardiol* 2011; 58: 2241–2247.
2. National Institute for Cardiovascular Outcome Research. *National congenital heart disease audit report 2010–2013*. Annual public report. 25 September 2014. London: UCL.
3. Mogra R. Simplifying ultrasound assessment of the fetal heart: incorporating the complete Three Vessel View into routine screening. *Australas J Ultrasound Med* 2013; 16: 168–175.
4. Ko JM. Genetic syndromes associated with congenital heart disease. *Korean Circ J* 2015; 45: 357–361.
5. Sharland G. Fetal cardiac screening and variation in prenatal detection rates of congenital heart disease: why bother with screening at all? *Future Cardiol* 2012; 8: 189–202.
6. Bricker L, Garcia J, Henderson J, et al. Ultrasound screening in pregnancy: a systematic review of the clinical effectiveness, cost-effectiveness and women's views. *Health Technol Assess* 2000; 4: 1–193.
7. NHS England. Update on neonatal and antenatal detection of congenital heart disease (CHD). *New congenital heart disease review*, www.england.nhs.uk/wp-content/uploads/2014/09/chd-5-230914.pdf (2014, accessed 12 September 2017).
8. NHS Fetal Anomaly Screening Programme. *18⁺⁰ to 20⁺⁶ weeks fetal anomaly scan: national standards and guidance for England 2010*. 2010. Exeter: NHS Fetal Anomaly Screening Programme.
9. NHS Fetal Anomaly Screening Programme. *Two day 3VT staff training programme*. Leicester, UK: King Power Stadium, 2015.
10. NHS Fetal Anomaly Screening Programme. *Programme handbook*. 2015, www.gov.uk/government/uploads/system/uploads/

- attachment_data/file/456654/FASP_programme_handbook_August_2015.pdf (2015, accessed 12 September 2017).
11. Escobar-Diaz M, Freud L, Bueno A, et al. Prenatal diagnosis of transposition of the great arteries over a 20-year period: improved but imperfect. *Ultrasound Obstet Gynecol* 2015; 45: 678–682.
 12. Shih JC, Huang SC, Lin CH, et al. Diagnosis of transposition of the great arteries in the fetus. *J Med Ultrasound* 2012; 20: 65–71.
 13. Ravi P, Mills L, Fruitman D et al. Population trends in prenatal detection of transposition of great arteries: impact of obstetrical screening ultrasound guidelines. *Ultrasound Obstet Gynecol*. Epub ahead of print 24 April 2017. DOI: 10.1002/uog.17496.
 14. NHS England. *New congenital heart disease review. Recommendations to improve antenatal and neonatal detection of congenital heart disease (CHD)*, <https://www.england.nhs.uk/wp-content/uploads/2015/06/chd-a-objective-paper.pdf> (2015, accessed 10 October 2017).
 15. Bravo C, Gámez F, Pérez R, et al. Fetal aortic arch anomalies. *J Ultrasound Med* 2016; 35: 237–251.
 16. Gustapane S, Leonbromi M, Khalil A, et al. Systematic review and meta-analysis of persistent left superior vena cava on prenatal ultrasound: associated anomalies, diagnostic accuracy and postnatal outcome. *Ultrasound Obstet Gynecol* 2016; 48: 701–708.