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Antenatal Screening for Congenital Heart Disease: A Single Center 11-Year Study of the Incidence, Antenatal Detection Rate, and Outcomes of Fetal Cardiac Anomalies

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Abstract

Objectives This article describes the incidence, detection rate, and birth outcomes of congenital heart disease (CHD) within a single center over an 11-year period.

Methods A database of patients diagnosed with CHD on antenatal ultrasound or within 12 months of delivery was collated from January 2010 to December 2020. A retrospective review of records was performed to establish the incidence of CHD and the antenatal detection rate (ADR). A Fisher's exact test was used to investigate the association between the type of CHD, the presence of a genetic abnormality, extracardiac anomalies, and the ADR.

Results The incidence of CHD was 4.3 per 1,000 maternities ($n = 161$). Fifty-five percent of anomalies were diagnosed antenatally. Twenty-seven percent underwent termination of pregnancy. Seventy-three percent of cases were alive at the end of follow-up. Patients with a major form of CHD were more likely to receive an antenatal diagnosis compared with those with other forms of CHD (64.9% vs. 39.1%, p 0.002). The presence of extracardiac abnormalities was associated with a higher ADR.

Conclusion The incidence of CHD was 4.3 per 1,000 maternities. Most major cardiac anomalies were diagnosed antenatally. Detection rates varied depending on the nature of the lesion and the presence of other congenital anomalies.

Implications for Clinical Practice Cardiac anomalies are the most common form of birth defect. Reported incidence rates lie between 4 and 20 per 1,000 live births. This study describes the incidence, pregnancy outcomes, and ADR of cardiac anomalies within one Scottish health board. It provides insight into the effectiveness of a national screening program in detecting CHD and the factors that influence ADR. Therefore, it can be used to more effectively counsel patients on the strengths and limitations of antenatal ultrasound for detecting CHD.

Keywords
- heart defects
- congenital
- fetal screening
- antenatal diagnosis

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Introduction

Cardiac anomalies are the most common form of birth defect.[1] Reports on the incidence of such anomalies vary across literature, depending upon study design and population.[2] Reported rates lie between 4 and 20 per 1,000 live births.[2,3] Antenatal detection of congenital heart disease (CHD) is important as it allows clinicians time to counsel parents regarding prognosis appropriately and plan ongoing care.[4] In turn, this ensures that the birth can be planned to take place in a center with appropriate expertise in managing complex CHD if required.

Although there are several risk factors for CHD, most affected pregnancies are in low risk patients.[5] In the United Kingdom, CHD is routinely screened for during the 20-week fetal anomaly scan. Acceptable thresholds have been established by the national screening program for four major cardiac anomalies, namely: tetralogy of Fallot (TOF) ($\geq$ 55%), transposition of great arteries (TGA) ($\geq$ 70%), atrioventricular septal defect (AVSD) ($\geq$ 50%), and hypoplastic left heart syndrome (HLH) ($\geq$ 80%).[6] We reviewed pregnancies booked within National Health Service (NHS) Fife between January 2010 and December 2020. NHS Fife is a health board in the South-East of Scotland that serves a population of over 370,000.[7] It covers a wide rural area with varied geography and several centers of population.[7] According to the Scottish Index of Multiple Deprivation, 19.6% of data zones within Fife rank within the 20% most deprived in Scotland.[8] We describe the incidence, pregnancy outcomes, and antenatal detection rate (ADR) of cardiac anomalies within this population.

Materials and Methods

Ethical approval was gained via registration of the project with the local audit office. A database of all pregnancies diagnosed with CHD on antenatal ultrasound or within 12 months of delivery was collated over an 11-year period from January 2010 to December 2020 by a fetal medicine midwife with dedicated audit time. Cases diagnosed postnatally by the local pediatric team were added to the database to allow continued review of missed cases. Cases were only included if CHD was diagnosed on neonatal echocardiography, postmortem, or fetal echocardiography if the patient declined a postmortem following a termination of pregnancy (TOP) or intrauterine death (IUD). A retrospective review of health records was conducted for all cases. Data was collected on maternal age, gestational age at diagnosis, type of cardiac anomaly, genetic abnormalities, extracardiac congenital abnormalities, pregnancy outcome, place of birth (local vs. tertiary center), neonatal death rate, and need for postnatal cardiac surgery. Cases of atrial septal defect (ASD) and patent ductus arteriosus (PDA) were excluded as PDA cannot be diagnosed on antenatal ultrasound and ASD is challenging to diagnose antenatally due to the presence of the foramen ovale during fetal life.[1] Data was combined with information on the number of maternities to establish the incidence of cardiac anomalies within the population and the ADR for the various cardiac anomalies was calculated. A Fisher's exact test was used to assess whether there was any significant difference in the ADR for major CHD after the introduction of the 3-vessel view (3VV) and 3-vessel trachea (3-VT) view to screening standards in 2015 by comparing the ADR from 2010 to 2015 with the ADR during the period 2016 to 2020. Major cases were defined as those highlighted in national screening standards, namely, TOF, TGA, AVSD, and HLH, as well as those resulting in neonatal death or requiring cardiac surgery.

A Fisher's exact test was also used to evaluate whether there was any significant association between the severity of cardiac anomaly and the ADR. Cases of major CHD were compared with all other cardiac lesions. We also compared pregnancies with and without extracardiac anomalies on ultrasound, as well as those with and without genetic abnormalities.

Results

Incidence of CHD: There was a total of 37,356 pregnancies booked within NHS Fife over the 11-year study period, of which 4.3 per 1,000 maternities ($n = 161$) received a diagnosis of CHD. Two twin pregnancies were affected: one dichorionic diamniotic and the other monochorionic diamniotic. Only one twin was affected in each pregnancy.

An isolated ventricular septal defect (VSD) was the most common anomaly, making up 20.5% of the cases ($n = 33$). Note that 17.4% ($n = 28$) of cases were of AVSD, 9.9% ($n = 16$) HLH, 9.3% ($n = 15$) of TGA, 5.0% ($n = 8$) arrhythmia, and 4.3% ($n = 7$) TOF. Stenotic valvular lesions accounted for 7.5% of abnormalities ($n = 12$). A complete breakdown of cases can be seen in ►**Table 1**.

Pregnancy outcomes: The mean age of affected mothers was 30 (range 16–44). Fifty-five percent ($n = 88$) of anomalies were diagnosed in the antenatal period, with the majority detected before 24 weeks' gestation (81%, $n = 71$). Of those detected antenatally, just over one-quarter underwent TOP (27%, $n = 24$). ►**Table 2** describes the underlying diagnoses for each TOP and the association with extracardiac and genetic abnormalities.

Nine cases resulted in IUD. The gestational age at diagnosis of IUD ranged from 24 + 2 to 38 + 2 weeks. There were 11 cases of neonatal death, of which 8 cases were postsurgery. Seventy-three percent ($n = 117$) of cases were alive at the end of the follow-up period, with 48% of live births ($n = 61$) requiring cardiac surgery (►**Tables 3** and **4**). The majority of births took place in the local hospital, with only 14% occurring in a larger tertiary center.

Twenty percent ($n = 32$) of pregnancies were affected by genetic abnormalities. Thirteen were diagnosed antenatally and 19 postnatally. Of those pregnancies affected, trisomy 21 was the most common type of genetic abnormality ($n = 15$), followed by trisomy 18 ($n = 6$) (►**Table 5**). Twenty-one percent ($n = 36$) of cases had extracardiac anomalies detected on antenatal ultrasound.

ADR: The ADR varied depending on the type of cardiac anomaly. Hypoplastic left and right heart syndrome had a 100% ADR, whereas isolated VSD and aortic coarctation were diagnosed postnatally in most cases (►**Table 6**). Eighty

Table 1 Types of cardiac anomaly

Cardiac anomaly	Number of cases	% of all cases
Isolated ventricular septal defect	33	20.5
Atrioventricular septal defect	28	17.4
Transposition of great arteries	15	9.3
Hypoplastic left heart syndrome	16	9.9
Arrhythmia	8	5.0
Tetralogy of Fallot	7	4.3
Hypoplastic right heart syndrome	2	1.2
Aortic coarctation	5	3.1
Valvular stenosis[a]	12	7.5
Outflow tract abnormality	4	2.5
Isolated right aortic arch	2	1.2
AV VA discordance	3	1.9
VSD and valvular stenosis	9	5.6
VSD and other cardiac anomaly	9	5.6
Miscellaneous	8	5.0
Total	161	

Abbreviations: AV, atrioventricular; VA, ventriculoarterial; VSD, ventricular septal defect.
[a]Includes pulmonary and aortic stenosis.

Table 3 Pregnancy outcomes

Pregnancy outcome	Percentage of cases
Termination of pregnancy	14.9% ($n = 24$) of total cases 27.2% of total cases diagnosed antenatally
Intrauterine death	5.6% ($n = 9$)
Neonatal death	6.8% ($n = 11$) $n = 8$ postsurgery; $n = 3$ presurgery
Surgery postdelivery	37.9% of total cases ($n = 61$) 47.7% of live births
Unknown	0.6% ($n = 1$)
Alive at 1 year postnatal	72.7% ($n = 117$)

percent of TGA cases and 71% of AVSDs were diagnosed antenatally. The ADR for TOF was 57%. The ADR for duct-dependent lesions ($n = 41$) was 78%. The percentage of cases diagnosed antenatally varied year by year, with no clear trend emerging. ►**Fig. 1** and ►**Table 7** demonstrate the difference in the ADR for all cases of CHD and cases of major CHD only each year. There was no significant difference (p 0.671) in the ADR for major CHD when comparing cases diagnosed between 2010 to 2015 and 2016 to 2020 despite changes in screening guidelines.

Patients with a major form of CHD were more likely to receive an antenatal diagnosis compared with those with other forms of CHD (64.9% vs. 39.1%, p 0.002). Pregnancies with extracardiac anomalies were more likely to be diagnosed with CHD antenatally when compared with pregnancies with an isolated cardiac anomaly on ultrasound (83.3% vs. 46.4%, $p < 0.001$). However, there was no significant difference in the ADR between pregnancies with a genetic abnormality (detected either antenatally or postnatally) and those without (68.8% vs. 51.2%, p 0.078).

Discussion

The incidence of CHD in our study population was 4.3 per 1,000 maternities. This is lower than the incidence reported in other studies[2,3] and in European data on CHD, with rates of 8 per 1,000 births reported between 2005 and 2021.[9] However, this study only includes those diagnosed with CHD during the antenatal period and the first 12 months of life, excluding milder cases, which are less likely to be diagnosed during infancy.[2] The incidence of AVSD was higher than that reported in European data on CHD (7.5 per 10,000 vs. 4.6 per

Table 2 Termination of pregnancy—underlying diagnoses

Cardiac anomaly	Total number of cases	Isolated cardiac abnormality	With genetic abnormality	With extracardiac abnormality	With genetic and extracardiac abnormalities
Atrioventricular septal defect	2	0	1	0	1
Tetralogy of Fallot	1	1	0	0	0
Hypoplastic left heart syndrome	7	5	1	1	0
Transposition of great arteries	4	4	0	0	0
Hypoplastic right heart syndrome	1	1	0	0	0
Ventricular septal defect	2	0	0	1	1
Ventricular septum defect + other cardiac anomaly	4	0	0	3	1
Valvular stenosis	2	0	0	1	1
Abnormal aortic and ductal arches	1	0	0	1	0

Table 4 Birth outcomes for four screened cardiac anomalies and VSD

Cardiac anomaly	Total cases	TOP	IUD	Neonatal death	Cardiac surgery	Alive at end of follow-up
Atrioventricular septal defect	28	2	6	3	11	17
Tetralogy of Fallot	7	1	0	1	3	5
Hypoplastic left heart syndrome	16	7	2	1	6	6
Transposition of great arteries	15	4	0	1	10	10
Ventricular septal defect	32	2	0	1	9	29

Abbreviations: IUD, intrauterine death; TOP, termination of pregnancy; VSD, ventricular septal defect.

Table 5 Association with genetic abnormality

Type of genetic abnormality	Percentage of total cases
Trisomy 21	8.9 ($n=15$)
Trisomy 13	0.6 ($n=1$)
Trisomy 18	3.6 ($n=6$)
DiGeorge syndrome	1.2 ($n=2$)
Noonan's syndrome	1.8 ($n=3$)
Other[a]	3.6 ($n=5$)
Total cases with genetic abnormality	19.9 ($n=32$)

[a]Triploidy $n=1$; trisomy 3 $n=1$; balanced translocation chr 8 + 9 $n=1$; 1.2 megabase deletion $n=1$; 8p23.1 microduplication $n=1$.

Table 6 Antenatal detection rate by cardiac anomaly

Cardiac anomaly	Percentage diagnosed antenatally
Atrioventricular septal defect	71.4 ($n=20$)
Tetralogy of Fallot	57.1 ($n=4$)
Hypoplastic left heart syndrome	100 ($n=16$)
Transposition of great arteries	80 ($n=12$)
Arrhythmia	63 ($n=5$)
Isolated VSD	18 ($n=6$)
Hypoplastic right heart syndrome	100 ($n=2$)
Coarctation of aorta	20 ($n=1$)

Abbreviation: VSD, ventricular septal defect.

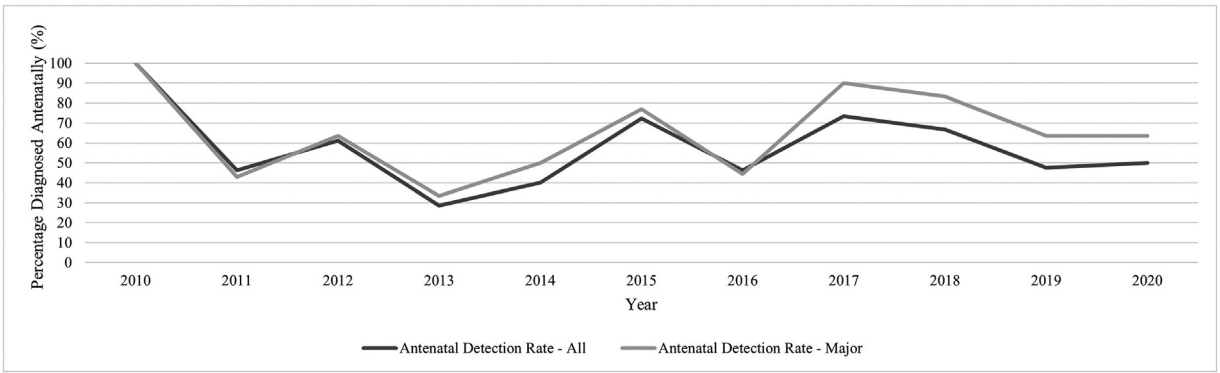

Fig. 1 Antenatal detection rate—all congenital heart disease (CHD) vs. major CHD.

Table 7 Antenatal detection rate per year (all CHD cases vs. major CHD cases)

Year	Total number of cases – all CHD	Cases diagnosed antenatally – all CHD	Antenatal detection rate (%) – all CHD	Total number of cases – major CHD	Cases diagnosed antenatally – major CHD	Antenatal detection rate (%) – major CHD
2010	6	6	100	5	5	100
2011	13	6	46.1	7	3	42.9
2012	18	11	61.1	11	7	63.6
2013	14	4	28.6	6	2	33.3
2014	20	8	40	8	4	50
2015	18	13	72.2	13	10	76.9
2016	13	6	46.2	9	4	44.4
2017	15	11	73.3	10	9	90
2018	9	6	66.7	6	5	83.3
2019	21	10	47.6	11	7	63.6
2020	14	7	50	11	7	63.6

Abbreviation: CHD, congenital heart disease.

10,000), while rates of TOF were lower (1.9 per 10,000 vs. 3.6 per 10,000).[9] It is difficult to say whether this represents a true difference in incidence for this region compared with international levels. Lower rates of TOF may reflect the challenges associated with identifying cases diagnosed postnatally (discussed further in the "Study Limitations" section) given that only 57% of cases were diagnosed antenatally.

In keeping with previous studies, we found that an isolated VSD was the most common form of CHD.[10] It is likely that the incidence of VSD is higher in this cohort than in the general population as there is a high spontaneous closure rate.[11] As such, rates in a neonatal cohort are known to be higher than in the adult population. The ADR was only 18%, which is lower than that reported in a previous study conducted in the Netherlands, which described an ADR for VSDs of 39% after the introduction of a national screening program.[12] However, it is important to note that the population examined differed from that of the current study in that it included only patients with severe CHD (defined as a cardiac lesion that was possibly life-threatening or likely to require intervention within 1 year of delivery). In contrast, only 9 out of 33 cases of VSD in this study required cardiac surgery, and there was only one case of neonatal death in a patient who also had multiple other extracardiac anomalies. It is accepted that less severe lesions are more difficult to diagnose antenatally, perhaps explaining our lower ADR.[5] Moreover, arguably, detecting such lesions on routine screening is less crucial than other major cardiac lesions, given that antenatal detection has less influence on initial neonatal management.[5]

The ADR for the four screened-for lesions was higher than the acceptable thresholds set out by national screening standards for cases of TOF, TGA, HLH, and AVSD. Moreover, the ADR for duct-dependent lesions was nearly 80%. This is important as infants with such lesions can deteriorate quickly postnatally when the ductus arteriosus closes and require a prostaglandin infusion to maintain duct patency.[13] The antenatal diagnosis of duct-dependent CHD allows appropriate care planning and prevents delays in commencing prostaglandin infusions that can have a deleterious effect on patient prognosis.[13] The high ADR for such lesions in this cohort demonstrates the effectiveness of current antenatal screening protocols in identifying critical CHD and improving patient care.

The majority of anomalies were detected prior to 24 weeks, giving time for counseling patients on their available options, including TOP. Indeed, the average gestation of TOP was $20+6$ (range $16+1$ to $24+0$). Although in the United Kingdom, termination for the fetal anomaly is available at any point during a pregnancy,[14] late second and third trimester terminations for fetal anomaly are associated with increased maternal psychological morbidity.[15] Earlier diagnosis allows patients time to consider all options and is likely to improve the patient experience and avoid the need for additional interventions such as feticide.[14] Moreover, early antenatal diagnosis also permits referral to tertiary centers for complex cardiac anomalies and, thus, appropriate birth planning.

The TOP rate was 27% for all cases of CHD diagnosed antenatally. TOP rates for CHD vary across the literature, with one study by Pavlicek et al[16] reporting rates of 49% for cases of CHD in the Czech Republic, while another study by Montaguti et al reported a TOP rate of just 19.5% among patients with any form of isolated CHD.[17] Such differences could be accounted for by variations in the study populations, with Pavlicek et al including only patients with lesions likely to require cardiac surgery, while the current study includes all cases of CHD. Indeed, both of the aforementioned studies found that higher rates of TOP were associated with increasing severity of CHD.[16,17] Moreover, many of the cases that resulted in TOP in this study also had genetic abnormalities or extracardiac lesions. This may have

been the primary driver of the patient's decision to terminate the pregnancy (►**Table 2**) and could account for the higher TOP rate found compared with Montaguti et al. These previous studies were conducted in countries with different laws and attitudes toward TOP, and as such, differences in TOP rates may also result from these cultural and political variations.

ADR: The ADR of CHD varied over the study period. In 2010, all cases of major CHD were detected antenatally compared with less than 50% in the years 2011, 2013, and 2016 (►**Fig. 1**, ►**Table 7**). This may be explained by differences in the types of CHD detected during these years. In 2010, the incidence of major CHD was only 1.3 per 1,000 maternities ($n = 5$). All but one patient had a condition included in national screening guidance. In comparison, the years with the lowest ADR had higher levels of lesions not routinely screened for, including higher levels of VSDs. The case mix was, therefore, comprised of a greater number of lesions that are challenging to diagnose using antenatal echocardiography.[18] Indeed, patients with a major CHD were significantly more likely to be diagnosed antenatally than those with other cardiac lesions (p 0.002). The major CHD group was composed largely (68%) of the four screened for lesions. The higher ADR for these forms of CHD may be a result of focused scanning to check for such lesions as practitioners strive to meet national standards. Indeed, it suggests that the creation of set standards for antenatal screening and effective training among sonographers improves the antenatal diagnosis of these types of CHD. It also reflects the better sensitivity of fetal ultrasound to detect more severe lesions.

During the course of the study, there were updates in ultrasound training and imaging standards with the introduction of the 3VV and 3VT into standard antenatal screening in 2015. We expected that this would result in an improvement in the ADR of CHD. However, there was no significant difference in the ADR when comparing cases of major CHD diagnosed between 2010 to 2015 and 2016 to 2020 (p 0.671). The 3VV and 3VT views alert scanners to abnormalities of the outflow tracts[19] and have been found to improve the detection of TOF and TGA when introduced to screening protocols in other countries.[20] There were only 2 cases of TOF and 4 of TGA diagnosed after 2015, and therefore, it is likely that the statistical analysis lacked the power to detect such differences.

Pregnancies with extracardiac anomalies were more likely to receive an antenatal diagnosis of CHD than isolated cardiac lesions. If structural anomalies are detected on the anomaly screening ultrasound, then patients are routinely referred to a fetal medicine clinician for further ultrasound evaluation. More detailed and frequent ultrasound examinations are therefore performed resulting in the detection of CHD that might have been missed on routine screening. In comparison, there was no difference in the ADR between pregnancies with and without genetic abnormalities. It is, however, important to note that the majority of genetic abnormalities were diagnosed postnatally and, as such, are less likely to influence scanning practices and detection rates.

Study Limitations

The results of this confined maternity cohort study may not be applicable to the wider obstetric population. The study population includes patients cared for within one Scottish health board; therefore, incidence rates may not be representative of the wider U.K. population. However, as fetal anomaly screening is standardized across the U.K. this study still provides an insight into the effectiveness of antenatal screening for CHD in the U.K.

Data was collected on patients diagnosed antenatally and any patient presenting to the local pediatric department with a cardiac anomaly within the first 12 months following birth. Patients who received care for CHD diagnosed postnatally in other health boards, those who died from undiagnosed CHD, or those who presented later than 12 months were not included in the study. This risks underrepresenting the true incidence of CHD. National databases on congenital anomalies diagnosed in Scotland have only recently started collecting data on the method of diagnosis of fetal anomalies.[21] Going forward, there is potential to analyze such data to calculate the national and local ADR for CHD and thus allow better counseling of patients on the risk of false negative antenatal scans.

Conclusion

The incidence of CHD for this cohort was 4.3 per 1,000 maternities. Most major cardiac anomalies were diagnosed antenatally. Detection rates varied depending on the nature of the lesion and the presence of other congenital anomalies. The majority of lesions diagnosed antenatally are detected before 24 weeks' gestation, allowing time for appropriate counseling and birth planning. Going forward, this adds to the literature on the effectiveness of antenatal ultrasound in identifying CHD.

Note

This original research has never been presented or published.

Authors' Contributions

N.P. conceived and designed the study. I.C. and E.C. contributed to data collection. E.C. performed data analysis and wrote the manuscript with supervision from N.P. All authors have reviewed the final manuscript.

Ethical approval

This retrospective review of health records was registered with the local audit office and conformed to the ethical principles outlined in the Declaration of Helsinki.

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None.

Conflict of Interest

None declared.

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