

Original Article

Accurate diagnosis of CHD by Paediatricians with Expertise in Cardiology

Hannah C. Jacob,¹ Hannah Massey,¹ Robert W. M. Yates,² A. Wilfred Kelsall³

¹*School of Clinical Medicine, University of Cambridge, Cambridge;* ²*Paediatric Cardiology, Great Ormond Street Hospital, London;* ³*Neonatal Intensive Care Unit, Addenbrooke's Hospital, Cambridge, United Kingdom*

Abstract *Introduction:* Paediatricians with Expertise in Cardiology assess children with a full history, examination, and often perform an echocardiogram. A minority are then referred to an outreach clinic run jointly with a visiting paediatric cardiologist. The accuracy of the echocardiography diagnosis made by the Paediatrician with Expertise in Cardiology is unknown. *Materials and methods:* We conducted a retrospective review of clinic letters for children seen in the outreach clinic for the first time between March, 2004 and March, 2011. Children with CHD diagnosed antenatally or elsewhere were excluded. We recorded the echocardiography diagnosis made by the paediatric cardiologist and previously by the Paediatrician with Expertise in Cardiology. *Results:* The Paediatrician with Expertise in Cardiology referred 317/3145 (10%) children seen in the local cardiac clinics to the outreach clinic over this period, and among them 296 were eligible for inclusion. Their median age was 1.5 years (range 1 month–15.1 years). For 244 (82%) children, there was complete diagnostic agreement between the Paediatrician with Expertise in Cardiology and the paediatric cardiologist. For 29 (10%) children, the main diagnosis was identical with additional findings made by the paediatric cardiologist. The abnormality had resolved in 17 (6%) cases by the time of clinic attendance. In six (2%) patients, the paediatric cardiologist made a different diagnosis. In total, 138 (47%) patients underwent a surgical or catheter intervention. *Discussion:* Paediatricians with Expertise in Cardiology can make accurate diagnoses of CHD in children referred to their clinics. This can allow effective triage of children attending the outreach clinic, making best use of limited specialist resources.

Keywords: Echocardiogram; paediatrician; expertise; diagnosis

Received: 28 December 2015; Accepted: 30 October 2016; First published online: 7 June 2017

CHD AFFECTS AROUND 1% OF CHILDREN IN THE United Kingdom.¹ Increasingly in the United Kingdom, children and young people suspected of having CHD are referred by general practitioners or other paediatricians to local Paediatricians with Expertise in Cardiology to be seen in a “local cardiac clinic”.² This is a paediatrician who has built up knowledge and skills to assess, diagnose, and manage children with CHD. The Paediatricians with Expertise in Cardiology undertake a history, examination, and may perform an echocardiogram, often in a “one-stop clinic”. Most children with normal hearts or very

minor anomalies can then be discharged or followed-up by the paediatrician locally.

In the small number of cases where a significant abnormality is detected, the child is referred to a visiting paediatric cardiologist's outreach clinic. These clinics are typically held in the same local hospital and are run jointly by the Paediatrician with Expertise in Cardiology and a visiting paediatric cardiologist, using the model recommended by the Kennedy Bristol Inquiry and the British Congenital Cardiac Association.^{3–5} The configuration of clinics in this way forms part of the recent NHS England-proposed standards, seeking to foster links between local hospitals and regional cardiology centres.⁶ The successful running of these joint clinics relies on accurate echocardiography diagnoses by the Paediatrician with

Correspondence to: A. W. Kelsall, Neonatal Intensive Care Unit, Addenbrooke's Hospital, Hills Road, Cambridge CB2 0QQ, United Kingdom. Tel: +01 2232 45151; E-mail: wilf.kelsall@nhs.net

Expertise in Cardiology.⁴ This ensures that the most appropriate children see the visiting specialist paediatric cardiologist in a timely manner and close to the child's home.^{7,8} Local clinics reduce the burden on families by avoiding high travel costs and minimising absence from school and work that is required for appointments at a distant tertiary centre. Meanwhile, children with less-serious structural abnormalities can be appropriately managed mostly in the local paediatrician's clinic and not in the outreach clinic.

Nurturing local paediatric expertise in cardiology has additional benefits. It is well documented that tertiary cardiology services are overstretched, and the capacity pressures could increase if plans to reduce the number of specialist paediatric cardiology centres nationally come to fruition.⁹ Local Paediatricians with Expertise in Cardiology can help shoulder some of this burden, provided they see sufficient numbers of patients to maintain their skills. Supporting high-quality local cardiology services may also benefit other departments and specialist services locally, such as neonatal units, paediatric ICUs, and emergency departments, even in the absence of tertiary cardiologists.^{10,11} Confirming the accuracy of the echocardiography diagnoses made is vitally important for patient safety and to establish the case for increasing the number of Paediatricians with Expertise in Cardiology.¹²

Previous studies have sought to compare the echocardiography accuracy of adult cardiologists and technicians with paediatric cardiologists.^{13,14} Others have looked at the diagnostic accuracy of non-specialist paediatricians by clinical examination,^{15,16} yet others have explored the accuracy of emergency physicians assessing particular aspects of cardiac function in the emergency department.¹⁷ No study to date has compared the diagnostic accuracy of Paediatricians with Expertise in Cardiology performing echocardiography with those of a paediatric cardiologist. We examined the echocardiography diagnosis made by both clinicians for children seen in an established joint cardiac clinic and recorded the outcome for these children.

Materials and methods

We conducted a retrospective review of clinic correspondence for children attending the specialist outreach clinic. Patients were identified from hospital patient information systems.

Study population

Those attending the paediatric cardiac outreach clinic for the first time between March, 2004 and March, 2011 were eligible for inclusion in this study. Children with antenatally diagnosed cardiac problems

and those who had already received a cardiac diagnosis from another centre whose care was then transferred to Cambridge were excluded. Those referred to the visiting paediatric cardiologist outreach clinic by clinicians other than the local Paediatrician with Expertise in Cardiology were also excluded.

Study design

Using electronic patient records, we reviewed the clinic letter written to the general practitioner for each child's first clinic visit. Where no letter was found, the patient's handwritten medical notes were retrieved to establish the diagnosis.

For each child, we recorded the echocardiography diagnosis made by the visiting paediatric cardiologist in the outreach clinic and the previous echocardiography diagnosis made by the local Paediatrician with Expertise in Cardiology who had been in post for 12 years at the start of this study period. We also recorded any catheter or surgical interventions undertaken and the outcome for the patient, including discharge from clinic or death. The age and sex of each patient were also recorded.

Data analysis and ethics

Data were entered anonymously into a Microsoft Excel 2010 spreadsheet, and the same programme was used for data analysis. The study was exempted from ethics approval by the hospital ethics committee as it was deemed a service evaluation.

Results

A total of 317 new patients with no antenatal diagnosis were seen at the outreach cardiac clinic over the 7-year study period. Of these, 296 were eligible for inclusion in the study (see Table 1). The patients seen in the outreach clinic represented 10% (317/3145) of those seen over the same time period by the Paediatrician with Expertise in Cardiology in the local cardiac clinic.

Patient characteristics

Of the included patients, 171 (58%) were female. The median age of the children at their first outreach clinic appointment was 1.5 years (range 1 month–15.1 years).

Diagnosis by echocardiography: paediatric cardiologist

The most commonly diagnosed lesion in the clinic was atrial septal defect (63, 21%), followed by ventricular septal defect (46, 16%) and patent arterial duct (44, 15%). The range of diagnoses recorded is shown in Table 2.

Table 1. Patient seen in the outreach clinic during the study period and reasons for exclusion.

Criterion	Number of patients
Total new patients	317
Diagnosis already made by another centre	19
Referred by community paediatrician	1
Referred by emergency department	1
New patients included in final analysis	296

Table 2. Diagnoses made by echocardiogram in the clinic.

Diagnosis	Number of patients (%)
Atrial septal defect	63 (21%)
Ventricular septal defect	46 (16%)
Patent arterial duct	44 (15%)
Pulmonary stenosis	26 (9%)
Aortic stenosis	21 (7%)
Complex cyanotic CHD	17 (6%)
Other valvular (e.g. mitral regurgitation)	15 (5%)
Arrhythmia	13 (4%)
Coarctation of the aorta	10 (3%)
Dilated cardiomyopathy	9 (3%)
Aortic root dilatation	8 (3%)
Family history of CHD or sudden cardiac death	7 (2%)
Ventricular hypertrophy	6 (2%)
Atrioventricular septal defect	2 (<1%)
Other	9 (3%)

Comparison of echocardiography diagnosis

The comparison of echocardiography diagnoses made by the Paediatrician with Expertise in Cardiology and the visiting paediatric cardiologist is shown in Figure 1. For 244 (82%) children, there was complete diagnostic agreement. In a further 29 (10%) cases, there was agreement about the key findings with an additional diagnosis made by the paediatric cardiologist – for example, pulmonary regurgitation was diagnosed as well as tricuspid regurgitation.

In 17 (6%) children, defects such as a patent arterial duct, patent foramen ovale, and small ventricular septal defects had resolved by the time they visited the outreach clinics, several weeks or months after the initial consultation with the Paediatrician with Expertise in Cardiology. In six (2%) cases, the main diagnosis on echocardiography differed between the paediatric cardiologist and the local Paediatrician with Expertise in Cardiology. These cases are detailed in Table 3.

Interventions

Almost half (138, 47%) of the children underwent an intervention during the study period. This included 68 (23%) children who had a surgical procedure and

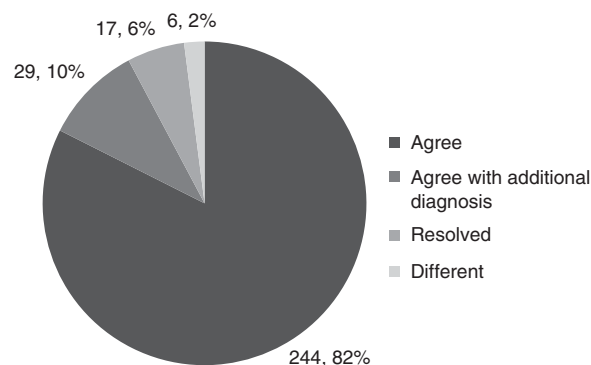


Figure 1. Comparison of echocardiography diagnoses made by visiting paediatric cardiologists and Paediatrician with Expertise in Cardiology (n, % total).

Table 3. Cases where the diagnosis made by the Paediatrician with Expertise in Cardiology (PEC) differed from that made by the visiting paediatric cardiologist (VPC).

Diagnosis made by PEC	Diagnosis made by VPC
Mitral valve regurgitation	Aortic regurgitation
Pulmonary stenosis	Aortic stenosis
Mild Ebstein's anomaly, tricuspid valve	Pulmonary stenosis
Normal heart (with family history of sudden death)	Mild pulmonary stenosis
Atrial septal defect with dilated right heart	Scimitar syndrome
Normal heart (with obvious murmur)	Apical ventricular septal defect

66 (22%) who had a catheter intervention. Among all, four (1.4%) children had both surgical and catheter interventions. Of the 158 (53%) not undergoing intervention, the vast majority had CHD (see Fig 2). These numbers are likely to be an underestimate of the true intervention rate, as a proportion of these children may well have undergone procedures after the study period.

Outcome

The majority of patients seen in the outreach clinic were followed-up by the visiting paediatric cardiologist in the outreach clinic (179, 60%) for the duration of the study period. The outcome for all study participants is shown in Table 4.

Discussion

Referral to specialist services

Our study demonstrates that a Paediatrician with Expertise in Cardiology who had been in post for 12 years at the start of this study can act as a safe

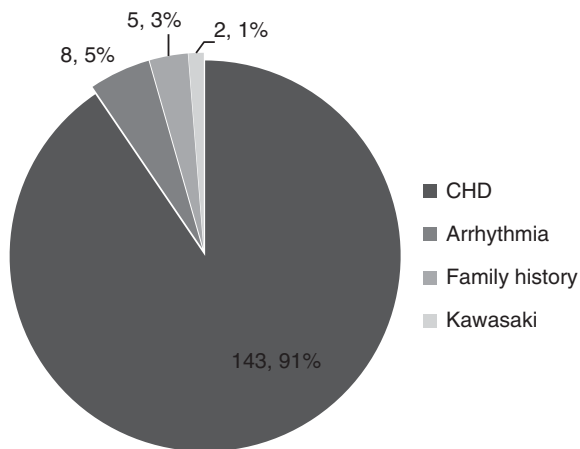


Figure 2. Diagnoses of children not undergoing catheter or surgical intervention during the study period (n, % total cohort).

Table 4. Outcome for children seen in the outreach clinic during the study period.

Outcome	Number of patients (%)
Follow-up by paediatric cardiologist	179 (60%)
Discharged from follow-up	65 (22%)
Moved out of area	20 (7%)
Followed-up by Paediatrician with Expertise in Cardiology	15 (5%)
Transitioned to adult cardiology	13 (4%)
Died	4 (1%)

and effective filter for referrals to a paediatric cardiologist. Accurate echocardiograms, in combination with a detailed history and examination, enable experienced paediatricians to safely and effectively triage patients before attendance at the cardiac outreach clinic. Only those requiring input from a paediatric cardiologist are referred to the outreach clinic run jointly with a visiting paediatric cardiologist, making the best use of the limited specialist resources available.⁸

Children seen by the paediatric cardiologist in the outreach clinic had a high likelihood of requiring either surgical or catheter intervention with almost half undergoing a procedure within the study period. This further suggests that Paediatricians with Expertise in Cardiology are very effective in selecting high-risk patients requiring specialist input and intervention. This is especially important given the proposed standards and service specification recommendations of NHS England's ongoing CHD review.⁶ This study supports increasing the number of Paediatricians with Expertise in Cardiology to deliver high-quality local services.

Diagnostic agreement and safety

In the vast majority of cases, there was complete diagnostic agreement on echocardiography between the local Paediatrician with Expertise in Cardiology and the paediatric cardiologist. Importantly, in the few instances where there were differences in the final diagnosis, these children had already been referred to the outreach clinic, on the basis of the echocardiogram performed by the Paediatrician with Expertise in Cardiology. Paediatricians with Expertise in Cardiology are in a unique position to perform a comprehensive assessment of children and use this to determine the need for tertiary referral.¹⁸ We believe that the ability to integrate all the clinical information available provides a higher standard of care than a service where an echocardiogram is performed by a sonographer who currently would not be able to clinically assess the child. Although sonographer-led services are important in the diagnostic pathway, when echocardiograms are not conducted simultaneously in clinic, important delays can be introduced in patient management.

One criticism of this study might be around potential missed cases and how they would be identified. We are aware of one child who was thought to have a closed atrial communication and was re-referred to the Paediatrician with Expertise in Cardiology with a persisting heart murmur 3 years after initial review and was found to have a large atrial septal defect that required surgical closure. We are confident, however, that there are no further children with a "missed" diagnosis who could have presented to another hospital. Importantly, no child has died in Cambridge who had been discharged from the local Paediatrician with Expertise in Cardiology's clinic, without seeing the paediatric cardiologist. In the East of England, there is a strong collaborative network of Paediatricians with Expertise in Cardiology who work closely together and meet regularly who would share such important information.

Patient experience

That the local Paediatrician with Expertise in Cardiology is able to perform accurate assessments of children has a considerable impact on the patient experience and the delivery of outpatient services. The vast majority of children can be seen in local cardiology clinics with only a small number requiring review by a paediatric cardiologist in the outreach clinic. Children and families avoid travelling long distances, minimising absence of children from school and parents from work. Most children with CHD can be followed-up in their local hospital where they will eventually transition to adult services. Receiving their paediatric care locally can

potentially help facilitate this process by increasing familiarity with the local hospital.

Benefits of expertise in cardiology locally

The Kennedy report was clear about the need to improve integration between primary, secondary, and tertiary care in the management of children with cardiac problems.³ By configuring services coordinated by a Paediatrician with Expertise in Cardiology, general practitioners build relationships and confidence with their local paediatric “cardiology” services. This optimises the appropriateness of referrals and develops strong communication links that are important for the ongoing management of children with CHD.

The presence of local Paediatricians with Expertise in Cardiology able to perform accurate echocardiograms also impacts positively on care provided in other departments, including neonatal and paediatric ICUs, where echocardiography skills among other staff may be more variable.¹¹ Paediatricians with Expertise in Cardiology may also be involved in local antenatal counselling of mothers with pregnancies affected by CHD, working with obstetricians and neonatologists to manage the initial postnatal care.¹⁹ Local expertise can facilitate coordinated care with other paediatric specialists who may be involved in the care of children with multiple medical problems. Paediatricians with Expertise in Cardiology may be able to facilitate the earlier repatriation of children who have had cardiac surgery from the tertiary specialist surgical centres to their local hospital. They may be able to coordinate local care for patients requiring palliative care in complex cases where cardiac problems are associated with other structural and chromosomal anomalies. This is important for the individual family and also important for wider paediatric cardiology services, easing pressure on specialist centres and releasing capacity for other patients requiring surgery or specialist care.

Challenges

Our study demonstrates the diagnostic accuracy that can be achieved by Paediatricians with Expertise in Cardiology, and we have outlined some of the benefits this may confer on services locally and regionally. This model of care faces challenges that have to be addressed in establishing and maintaining a high-quality service. The Paediatrician with Expertise in Cardiology needs allocated time at the tertiary specialist cardiac centre for continued professional development to maintain clinical skills. They should also be expected to attend the joint cardiac clinic locally when the visiting cardiologist is assessing children and performing echocardiograms.

Maintaining good communication between professionals based in different centres relies on technology and administrative staff to facilitate the transfer of images and timely delivery of correspondence. Paediatricians with Expertise in Cardiology should be able to discuss cases with cardiology colleagues at the tertiary centre using teleconferencing. Requests for training opportunities for paediatric trainees, medical students, and consultant colleagues abound and safeguards must be in place to prevent a single Paediatrician with Expertise in Cardiology and the visiting paediatric cardiologist in the outreach clinic from being overwhelmed by demands for training.

Limitations

Our study is limited to those children referred to the joint clinic by the Paediatrician with Expertise in Cardiology. We are not, therefore, able to comment on the accuracy of all the echocardiography diagnoses made by the Paediatrician with Expertise in Cardiology in the local clinic; however, children with a range of cardiac abnormalities were referred to the joint clinic having been accurately diagnosed, and there is no reason to suppose that the accuracy of these diagnoses differs markedly from those not referred.

Any study using historic correspondence is limited by the detail included in the clinic letters. The echocardiography reports included in the letters were detailed, but it is possible that where the paediatric cardiologist made additional diagnoses on echocardiogram these lesions had been seen by the local paediatrician but not mentioned in the original letter to the general practitioner.

Finally, we acknowledge that the Paediatrician with Expertise in Cardiology in this study is very experienced and has a well-established relationship with the specialist cardiac centre and network. It would be important not to extrapolate the degree of echocardiography accuracy achieved in this case to all similar services. Any attempt to establish a local service including a Paediatrician with Expertise in Cardiology would have to take account of the skills and experience of individual paediatricians. The importance of the role of the Paediatrician with Expertise in Cardiology has been recognised by the British Congenital Cardiac Association and Royal College of Paediatrics and Child Health with the development of an agreed training curriculum where paediatricians gain competencies in the final phase of their training including a 12-month placement in a specialist cardiac centre.²⁰

Conclusion

Paediatricians with Expertise in Cardiology make accurate diagnoses using echocardiography as part of a

comprehensive clinical assessment of children referred with CHD. Such an assessment results in appropriate referrals to outreach clinics run jointly with visiting paediatric cardiologists utilising limited resources effectively. This service can provide safe and sustainable care for children with CHD close to home.

Acknowledgements

None.

Financial Support

This research received no specific grant from any funding agency or from commercial or not-for-profit sectors.

Conflicts of Interest

None.

References

1. EUROCAT Prevalence Tables (2012). Retrieved December 10, 2015 from <http://www.eurocat-network.eu/accessprevalencedata/prevalencetables>
2. Andrews H, Singh Y. Review of paediatric cardiology services in district general hospitals in the United Kingdom. *Cardiol Young* 2016; 26: 528–531.
3. Kennedy I. Learning from Bristol: the report of the public inquiry into children's heart surgery at the Bristol Royal Infirmary 1984–1995. London, 2001. Retrieved December 8, 2015 from www.bristol-inquiry.org.uk
4. British Congenital Cardiac Association. Requirements for Provision of Outreach Paediatric Cardiology Services. British Congenital Cardiac Association, London, 2009.
5. Karupraswamy V, Kelsall W. Review of paediatric cardiology services in district general hospitals in the United Kingdom. *Arch Dis Child* 2009; 94: 327.
6. NHS England. Proposed congenital heart disease standards and service specifications. A consultation. Leeds, 2014. Retrieved December 10, 2015 from <https://www.england.nhs.uk/2014/09/chd-services/>
7. Massin MM, Masmoudi H, Dessy H, et al. Workload of ambulatory activities in a tertiary paediatric cardiac centre. *Arch Cardiovasc Dis* 2008; 101: 737–741.
8. Murugan SJ, Thomson J, Parsons JM, Dickinson DF, Blackburn ME, Gibbs JL. New outpatient referrals to a tertiary paediatric cardiac centre: evidence of increasing workload and evolving patterns of referral. *Cardiol Young* 2005; 15: 43–46.
9. Wagstaff MH, Rigby ML, Redington AN. Increasing workload and changing referral patterns in paediatric cardiology outreach clinics: implications for consultant staffing. *Heart* 1998; 79: 223–224.
10. Thyagarajan S, Chavan A, Al-Sabbagh A, Latifi S, Kelsall AW. The provision of cardiology services in a non-cardiac paediatric intensive care unit setting. *Arch Dis Child* 2010; 95: 1068.
11. Kluckow M, Seri I, Evans N. Echocardiography and the neonatologist. *Pediatr Cardiol* 2008; 29: 1043–1047.
12. Gibbs JL. Paediatricians subspecialising in cardiology: clinical governance, maintenance of expertise, and training. *Arch Dis Child* 2006; 91: 878–879.
13. Saraf RP, Suresh P, Maheshwari S, Shah SS. Pediatric echocardiograms performed at primary centers: diagnostic errors and missing links!. *Ann Pediatr Cardiol* 2015; 8: 20–24.
14. Ward CJ, Purdie J. Diagnostic accuracy of paediatric echocardiograms interpreted by individuals other than paediatric cardiologists. *J Paediatr Child Health* 2001; 37: 331–336.
15. Sackey AH. Prevalence and diagnostic accuracy of heart disease in children with asymptomatic murmurs. *Cardiol Young* 2015; 1–5.
16. Gokmen Z, Tunaoglu FS, Kula S, Ergenekon E, Ozkiraz S, Olgunturk R. Comparison of initial evaluation of neonatal heart murmurs by pediatrician and pediatric cardiologist. *J Matern Fetal Neonatal Med* 2009; 22: 1086–1091.
17. Longjohn M, Wan J, Joshi V, Pershad J. Point-of-care echocardiography by pediatric emergency physicians. *Pediatr Emerg Care* 2011; 27: 693–696.
18. Pushparajah K, Garvie D, Hickey A, Qureshi SA. Managed care network for the assessment of cardiac problems in children in a district general hospital: a working model. *Arch Dis Child* 2006; 91: 892–895.
19. Anagnostou K, Messenger L, Yates R, Kelsall W. Outcome of infants with prenatally diagnosed congenital heart disease delivered outside specialist paediatric cardiac centres. *Arch Dis Child Fetal Neonatal Ed* 2013; 98: F218–F221.
20. Royal College of Paediatrics and Child Health. A framework of competencies for the special interest module in paediatric cardiology. London, 2012. Retrieved December 9, 2015 from <http://www.rcpch.ac.uk/system/files/protected/page/Cardiology.pdf>