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Commentary by David Tanous, who is a visiting medical officer in cardiology at Westmead and the Royal Prince Alfred Hospital. His clinical and research interests are in adult congenital heart disease and heart disease in pregnancy.

Since the widespread introduction of open heart surgery for congenital heart disease (CHD) in infants and children from the 1960’s onward, the number of adult survivors has continued to grow. Today, survival to adulthood is the rule for approximately 95% of those affected. Consequently, the adult population with CHD is now thought to outnumber that of children for the first time, and adult congenital heart disease (ACHD) has become an emerging area of need for service provision.2,3

Almost all adults with moderate or severe CHD are survivors of childhood surgical intervention. However these individuals do not necessarily have normal cardiovascular health as a consequence. In fact, they are prone to ongoing haemodynamic and electrophysiologic issues which are associated with a unique set of risks. These include reduced exercise tolerance, arrhythmias, heart failure and sudden death, in addition to excess risks associated with pregnancy and surgery.2

Childhood CHD is managed within specialist services with ongoing follow-up, but it has recently become apparent that the transition to adulthood results in up to half of all patients being lost to follow-up.2 One Canadian study found that by the age of 22, 61% of childhood CHD survivors had been lost to specialist follow-up.2 A more recent UK paper which examined lost to follow-up rates in subjects with Tetralogy of Fallot identified that 24% of those with this severe form of CHD were not receiving specialist care. The same study found that young adults with CHD who were lost to follow-up had excess mortality rates compared to those who received specialist care.

Recently published Australasian guidelines for ACHD3 provide specific details of the types of specialist services which should be available to this population, and outline plans for managed transitions between childhood and adult services. However given the large population of ACHD who are already lost to specialist follow-up, there is clearly an important role for the general practitioner in identifying these patients and ensuring they are reconnected with the appropriate services.

Types and classifications of congenital heart defects

Classification of CHD

Patients with congenital heart disease have functionally significant structural abnormalities of the heart or great vessels.1 These are generally thought to arise from interactions between a genetic predisposition and environmental factors, and many forms of CHD have a strong genetic component.1 CHD can be classified in a number of different ways relating to the site and type of defect, the effect of the defect on haemodynamics and oxygenation, and the severity of disease resulting from the defect (see table 1).

<table>
<thead>
<tr>
<th>Table 1. Classification of CHD</th>
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<tbody>
<tr>
<td>Anatomical site</td>
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<tr>
<td>Haemodynamic effects (shunting)</td>
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<tr>
<td>Effects on oxygenation</td>
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<tr>
<td>Severity of disease</td>
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</table>

Key types of congenital heart defects6

Patent ductus arteriosus

Patent ductus arteriosus or PDA is defined as patency of the ductus arteriosus for ≥ 3 months in a full-term infant. This non-cyanotic abnormality causes primarily left-to-right shunting from the systemic to the pulmonary circulation, resulting in increased pulmonary blood flow and congestion, and increased pulmonary resistance. If untreated, complications can include infective endocarditis, pulmonary vascular disease and left ventricular failure. Treatment is closure of the ductus via catheter-based or surgical means.

Atrial septal defects

Single or multiple abnormal openings of the atrial septum, including a patent foramen ovale, are termed atrial septal defects (ASD). Regardless of size, these non-cyanotic defects are usually asymptomatic, and therefore rarely detected until later in life. Larger defects result in primarily left-to-right shunting between the atria, causing increased right ventricular loading and pulmonary blood flow and eventually dilatation of the right atria and ventricle. Undiagnosed ASD may result in palpitations, atrial flutter or atrial fibrillation developing in adulthood, and pulmonary vascular disease from later adulthood.

Abbreviations used in this review:

ACHD = adult congenital heart disease
ASD = atrial septal defect
AVSD = atrioventricular septal defect
CHD = congenital heart disease
CHD-PAH = PAH associated with CHD
PAH = pulmonary arterial hypertension
VSD = ventricular septal defect
Ventricular septal defects
The most common form of CHD, responsible for 25-30% of lesions, ventricular septal defects (VSD) are single or multiple openings in the ventricular septum. Defects resulting in small or moderate amounts of left-to-right shunting are generally asymptomatic, associated with low risk for development of pulmonary vascular disease in children, and may close spontaneously. Larger defects are also often asymptomatic immediately after birth, as the increased pulmonary vascular resistance of the neonate may limit any increased blood flow into the pulmonary circulation. However progressive increases in left-to-right shunting occur as pulmonary vascular resistance falls in the first few weeks following birth, resulting in symptoms including tachypnoea, diaphoresis (often during feeding), and failure to thrive. Without treatment those with severe defects may develop pulmonary vascular disease and heart failure.

Atrioventricular septal defects
Atrioventricular septal defects (AVSD) are defects of the atrioventricular canals and the upper ventricular, and lower atrial septum. Consequently they have physiological effects similar to those of ASDs and VSDs. They occur in up to 30% of individuals with Down syndrome. Severity of the defects can range from mild and asymptomatic, to severe cases with left-to-right shunting between both atria and ventricles, resulting in increased pulmonary circulation and symptoms including effort intolerance, tiredness, failure to thrive and recurrent infection. Longer term, AVSDs may result in increased pulmonary vascular resistance and pulmonary hypertension.

Pulmonary stenosis
Pulmonary stenosis, whereby circulation from the right ventricle into the pulmonary artery is obstructed, occurs in around 10% of CHD and can be associated with other abnormalities. The obstruction can occur in one or more locations in the ventricle or pulmonary artery, but valvular disease is the most common form. Mild valvular disease associated with a systolic murmur is generally asymptomatic and non-progressive. More severe forms are progressive and may require valvotomy. Neonates with severe disease may present with cyanosis as a consequence of right-to-left atrial shunting and right ventricular hypertrophy.

Tetralogy of Fallot
Responsible for up to 7% of all CHD, Tetralogy of Fallot is the most common cyanotic defect. It involves 4 separate defects; a VSD; an overriding aorta involving displacement of the aorta to the right of the root of the pulmonary artery and connections to both ventricles; valvular or arterial pulmonary stenosis; and right ventricular hypertrophy. Cyanosis occurs due to right-to-left shunting through the VSD, and may increase in severity under stress, for example feeding, crying or defaecating in the newborn. Early surgical repair is indicated for infants with this severe disorder.

Complete transposition of the great arteries
Complete transposition of the great arteries is a cyanotic form of CHD in which the sites where the aorta and pulmonary artery enter the heart are transposed, resulting in deoxygenated blood from the right ventricle entering the systemic circulation via the aorta, and oxygenated blood from the left ventricle being returned to the pulmonary circulation via the pulmonary artery. The immediate survival of infants with this disorder is dependent on mixing of the pulmonary and systemic circulations, which can be achieved by preventing closure of the ductus arteriosus with prostaglandin E, and enlargement of the foramen ovale using balloon atrial septostomy. Mixing may also be aided in the 50% of infants with this condition who also have VSDs. Surgical correction of the defect usually takes place within the first month of life before pulmonary vascular resistance reduces. However long-term complications of the surgery may remain into adulthood and include coronary insufficiency, supravalvular pulmonary stenosis, neoaortic regurgitation and dysrythmias.

Coarctation of the aorta
Coarctation is a localised narrowing of the aorta, commonly associated with other CHDs. It can occur proximal or distal to the junction with the ductus arteriosus, but in the vast majority of cases is located juxtaadventitial. This non-cyanotic condition increases afterload and generally manifests as hypertension in the upper extremities, and hypotension in the lower extremities. It is often asymptomatic and may not be identified until adulthood, but severe acute disease may present in the newborn as signs of heart failure. Untreated coarctation may lead to left ventricular hypertension and hypertrophy, and systemic hypertension. Patients with prior repairs can also develop late complications such as re-coarctation or formation of aneurysms.

Functional single ventricle anatomy
Individuals with this complex form of cyanotic CHD, such as hypoplastic left heart syndrome, have only a single functional ventricle and are commonly diagnosed during routine prenatal ultrasound. All forms of the disorder result in mixing of the pulmonary and systemic circulations. As pulmonary vascular resistance declines after birth, the single ventricle preferentially pumps to the pulmonary circulation, resulting in compromised systemic circulation. As the ductus arteriosus closes, neonates become cyanotic and develop symptoms of heart failure. Early palliative surgical intervention is required for these critically unwell infants. Ventricular dysfunction, arrhythmias and thrombosis are common in this cohort. Patients in this group generally undergo staged procedures in childhood to separate the systemic and pulmonary circulations.

Non-congenital cardiovascular abnormalities
Functionally insignificant abnormalities of the great vessels and congenital arrhythmias including long QT and Wolf-Parkinson-White syndrome are generally not considered to be CHD. Likewise, abnormalities with a genetic basis such as hypotrophic or dilated cardiomyopathy which may be present at birth are not generally included since they are usually only detected later in life. In contrast, Marfan syndrome is often defined as CHD since it can be detected at birth, even though the cardiovascular lesions tend to appear later.

Severity of CHD
Most CHD is of a mild form which is asymptomatic. Those affected may not have significant murmurs, and lesions may resolve spontaneously. This category includes; small ASD, VSD and PDA; mild pulmonary stenosis; and bicuspid aortic valves without aortic stenosis or insufficiency. CHD of moderate severity is likely to be diagnosed in infancy or early childhood. Typical lesions include; large ASD; complex VSD; non-critical coarctation of the aorta; mild or moderate aortic stenosis or aortic insufficiency; and moderate pulmonary stenosis or insufficiency. These patients require specialist care but are generally not severely unwell. The category of severe CHD includes most patients who present as severely unwell as newborns or during early infancy. This includes all cyanotic disorders such as Tetralogy of Fallot, transposition of the great arteries and functional single ventricle. It also includes some acyanotic disorders such as AVSD, large VSD and severe pulmonic stenosis.

Comment: Children born with congenital heart disease may undergo surgery in the neonatal period or early childhood. Apart from patients who underwent surgical closure of atrial septal defects, patent ductus arteriosus or small-medium sized ventricular septal defects, most patients will need long-term follow-up. Some will need repeat surgical, interventional or electrophysiological procedures. A small subset of patients with CHD are diagnosed in adulthood, for example, adults with an atrial septal defect are often diagnosed by echocardiography during screening of an asymptomatic murmur. Some young adults with coarctation are diagnosed during screening for hypertension. Other patients who are diagnosed in childhood but who do not undergo surgery or intervention in childhood may also need long-term follow-up, for example patients with a bicuspid aortic valve with valve dysfunction. Follow-up is often based on the severity of the condition, though patients with unstable mild or moderate disease could be considered as having severe CHD, e.g. patient with a small ventricular septal defect who develops endocarditis also involving the pulmonary valve.

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Epidemiology of congenital heart defects

CHD is thought to be the most common form of birth defect, but estimates of the incidence of CHD are variable due to the use of differing definitions of CHD and differences in methods of assessing its presence. The primary reason for variation appears to be the number of tiny VSD included in the analysis. Studies which systematically screen all newborns within a cohort will detect almost all VSDs, however those which screen only symptomatic newborns or those with murmurs, and those which screen older children in whom most VSDs will have closed spontaneously, will report in lower incidences. For moderate and severe CHD, incidence is estimated to be approximately 6 per 1,000 live births (0.6%) at the lower end, or up to 19 per 1,000 (1.9%) if potentially serious bicuspid aortic valve defects are included in the definition. When mild CHD, including tiny VSDs, is included, incidence rates climb to 75 per 1,000 (7.5%).

Australian data for incidence of CHD are similarly variable, depending on the criteria used to define CHD. A selection of studies are presented below.

Congenital heart defects in central Australia

Authors: Bolisetty S et al
This retrospective cohort study investigated the incidence of CHD using data for all infants born in Central Australia between 1 January 1993 and 30 June 2000. The definition of CHD used was a broad, structural definition, and included congenital heart block and VSD of all sizes. Congenital defects which were excluded included simple bicuspid aortic valve abnormalities, clinically insignificant isolated peripheral pulmonary artery stenosis, and minor atrial shunts through defects < 5 mm wide which subsequently closed. Data were included for all children born at Alice Springs Hospital who were diagnosed with CHD following echocardiography, and children who presented with signs and symptoms suggestive of CHD, who subsequently had the diagnosis confirmed by echocardiography at the same centre. Overall incidence of CHD was 17.5 per 1,000 (95% CI 14.9-21.7). There was no statistically significant difference in CHD incidence in Aboriginal (19.0 per 1,000, 14.4-24.6) and non-Aboriginal infants (16.1 per 1,000, 12.0-21.1), relative risk 1.18 (0.81-1.72).
In their conclusions the authors acknowledge that the inclusion of minor lesions identified through echocardiography may have influenced these relatively high rates of CHD, although observed rates of major lesions were also higher than in similar Australian studies.

Reference: MJA 2004; 180:614-7
http://tinyurl.com/k2awund

2007 annual report of the South Australian Birth Defects Register

The annual report of the South Australian Birth Defects Register presents data for all structural and functional birth defects reported in the State which were identified in children before their 5th birthday. The average incidence of CHD from 1986 to 2007 was 11.9 per 1,000. VSDs were the most common defect (6%), followed by ASD (2.7%) and PDA (1.8%). Many abnormalities were not discovered during the post-birth hospital stay; on average for the period 1986-2007, 5-4% of CHD were identified after discharge from the birth hospital. For the year 2007, this figure was 28%.

Reference: Available on line at http://tinyurl.com/om8bvlk

Congenital heart disease: a 10 year cohort

Authors: Bowe C and Ramsay JM
The authors of this long-term, retrospective, population-based cohort study reported CHD incidence from the Western Australian Birth Defects Registry for the 10 year period 1980 to 1989. Data were reported for children with a diagnosis of CHD in the prenatal period, and up to the age of 6 years. CHD was defined as a structural abnormality of the heart or great vessels with actual or potential functional significance. This definition included congenital complete heart block, VSDs which closed spontaneously and isolated PDA remaining patent at 3 months in term infants. Peripheral vascular disorders were excluded. Amongst 233,502 live births, 1,787 were reported as having CHD, resulting in a total incidence of 7.65 per 1,000 live births. The majority (75%) had CHD alone, 17% also had other non-chromosomal birth defects, and 9% also had a chromosomal disorder, most commonly Down syndrome. CHD was more frequent in Aboriginal infants in comparison to non-Aboriginal infants, and those with birth-weights < 3kg.


Adult CHD in general practice

As noted earlier, large proportions of adults with CHD for whom specialist care is indicated are lost to specialist follow-up. Consequently there is an important role for the general practitioner in identifying these at risk patients within their practice and reconnecting them with appropriate specialist services.

Identification of ACHD in general practice

Arrhythmias
Adults with CHD are prone to arrhythmias as a consequence of a number of factors, including the type of defect, problems arising from surgical correction of the defect and haemodynamic issues. They may present with symptoms including palpitations, tachycardia, dizziness, syncope and signs of heart failure. Undiagnosed ASD may result in palpitations, atrial flutter or atrial fibrillation, those with corrected Tetralogy of Fallot often develop atrial or ventricular arrhythmias, and many patients with transplantation of the great arteries develop arrhythmias. Recurrent supraventricular arrhythmias are associated with functional single ventricle following Fontan repair. ACHD patients with arrhythmias may benefit from referral for electrophysiological evaluation.

Heart failure
Adult CHD patients may present with heart failure, particularly those with complex abnormalities. Heart failure is commonly associated with ACHD, and those at particular risk include those with corrected transposition of the great arteries (22%, or 32% with atrial switch surgery), and those with functional single ventricle and Fontan repair (up to 40%). Surgically correctable causes of heart failure, such as shunts, stenosis or valve insufficiency, should be treated where possible, with transplantation as a last resort in end-stage disease. Medical therapies may be appropriate for some patients.

Infectious endocarditis
ACHD patients at high risk of infectious endocarditis include those with complex and cyanotic conditions; those with prosthetic valves; and those with defects adjacent to implanted patches or conduits. Endocarditis prophylaxis is still required in these patients. Infective endocarditis may result from procedures including cardiac surgery, tonsillectomy and adenectomy, bronchoscopy involving biopsy or incision of the mucosa, and injuries to the mucosa, gingiva or apical dental region arising from dental procedures. Presenting symptoms include pyrexia, night sweats and embolism.

Pulmonary arterial hypertension and Eisenmenger’s syndrome
Adults with CHD, particularly those with uncorrected or late repair of left-to-right shunt lesions such as PDA, ASD, VSD and AVSD, may present with pulmonary arterial hypertension (PAH). CHD-PAH is a progressive disease. While patients with CHD-PAH may live for decades (even without treatment), once worsening symptoms develop, death can occur within a couple of years. The disease results from increased pulmonary arterial blood flow, which causes increased shear stress and circumferential stretch in the blood vessels. Endothelial dysfunction with release of growth factors promotes smooth muscle proliferation, thereby increasing pulmonary vascular resistance and right-ventricular hypertrophy. Eventually pulmonary vascular resistance becomes greater than systemic resistance, with the result that the direction of the shunt reverses. This is Eisenmenger’s syndrome, an end-stage disease in which cyanosis, often severe, is present, even at rest. Haematological changes including secondary erythrocytosis, and abnormalities of coagulation occur. There is an increased risk of thrombosis, concurrent with an increased risk of bleeding, including epistaxis, menorrhagia and haemoptysis. Other complications include infection, right ventricular failure, arrhythmias, sudden cardiac death, renal and hepatic dysfunction.
CSANZ Guidelines for management of adult CHD

The Cardiology Society of Australia and New Zealand (CSANZ) have provided recent guidelines\textsuperscript{1} which describe Standards of Care for ACHD. The focus is on “whole of life” planning, with emphasis on two key areas; effective transition of care from paediatric to adult services; and the establishment and maintenance of specialist ACHD services.

It is planned that a comprehensive ACHD service will be available for each 2-3 million population across Australasia, and that regional facilities will be available where there is an excess distance to the nearest comprehensive service. ACHD services will be staffed by ≥ 2 cardiologists with ≥ 12 months adult or paediatric CHD experience, a clinical nurse coordinator and nurse educator, and will have access to other relevant specialities with ACHD experience. Centres will also be able to facilitate access to services including cardiac MRI, electrophysiology services, an intensive care unit, a high risk obstetric unit, a heart and lung transplant service, clinical psychology, genetic counselling and social work. Contact details for existing Australasian ACHD centres are provided at the end of this section.

At the age of 16-18, children will be transitioned to their nearest ACHD service. A number of recommendations have been made in order to help to minimise lost to follow-up cases. It is recommended that transition should be overseen by a specialist transition nurse from the paediatric cardiac team, and that patients remain under paediatric services until their first appointment with ACHD services has been completed. Transition should be discussed and planned for with patients and families from an early stage, and transition plans should be provided to the patient’s GP. At transition, paediatric services should provide patients and families with a comprehensive information pack in written or electronic form which contains copies of their final clinical evaluation, relevant diagnostic tests such as imaging, and a copy of any reports from significant surgeries. Recommendations for frequency of follow-up for adults with different forms of CHD to ACHD services are also provided (see table 2).

Table 2: Recommendations for specialist follow-up care of adults with CHD\textsuperscript{2}

<table>
<thead>
<tr>
<th>Patient population</th>
<th>Frequency of follow-up</th>
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<tbody>
<tr>
<td>Young adults with repaired simple* CHD</td>
<td>Should be seen at least once in an ACHD service (unless discharged by their paediatric cardiologist)</td>
</tr>
<tr>
<td>Young adults with unrepaired CHD</td>
<td>Should be seen regularly by an ACHD service</td>
</tr>
<tr>
<td>All adults with non-simple* CHD</td>
<td>Should be seen regularly by an ACHD service, ± shared care by community-based specialists</td>
</tr>
</tbody>
</table>

*Simple CHD is small or repaired ASD, VSD or PDA without residual haemodynamic abnormality, or mild pulmonary or aortic valve disease.

Copies of the relevant Australasian, US and European guidelines for ACHD are available at the following sites.
http://www.isachd.org/content/updates-guidelines
http://www.isachd.org/content/updates-guidelines

Adult CHD referral centres

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<tr>
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<th>Address</th>
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<tbody>
<tr>
<td>Prince Charles Hospital</td>
<td>48 Liverpool Street, HOBART, TAS, 7000</td>
</tr>
<tr>
<td></td>
<td>Phone: (03) 6222 8620</td>
</tr>
<tr>
<td></td>
<td>Dr Nathan Dwyer</td>
</tr>
<tr>
<td>Royal Hobart Hospital</td>
<td>197 Wellington Street, PERTH, WA, 6000</td>
</tr>
<tr>
<td></td>
<td>Phone: 0404 894 279</td>
</tr>
<tr>
<td></td>
<td>Dr Andrew Bullock</td>
</tr>
<tr>
<td>Royal Adelaide Hospital</td>
<td>North Terrace, ADELAIDE, SA, 5000</td>
</tr>
<tr>
<td></td>
<td>Phone: (08) 8222 2910</td>
</tr>
<tr>
<td></td>
<td>Nurse: Peta King (pager 1388)</td>
</tr>
<tr>
<td></td>
<td>Dr Patrick Disney (Adult CHD)</td>
</tr>
<tr>
<td></td>
<td>Prof Peter Steele (PAH)</td>
</tr>
<tr>
<td>Royal Perth Hospital</td>
<td>197 Wellington Street, PERTH, WA, 6000</td>
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<td>Dr Andrew Bullock</td>
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<td></td>
<td>Dr Sang Yung</td>
</tr>
<tr>
<td>Royal Melbourne Hospital</td>
<td>300 Grattan Street, PARKVILLE, VIC, 3052</td>
</tr>
<tr>
<td></td>
<td>Phone: (03) 9342 7133</td>
</tr>
<tr>
<td></td>
<td>Nurse: Jane Wiles</td>
</tr>
<tr>
<td></td>
<td>A/Prof Leanne Grigg</td>
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</table>

Comment: International and Australasian guidelines have recommended referral of patients with moderate and complex CHD to ACHD centres. Loss to follow-up has led to poor outcomes in patients with ACHD. Loss to follow-up can be patient-related with many apparently “stable” patients who underwent early surgery considering themselves “cured”. Early detection of problems (e.g. patient with Tetralogy of Fallot repair in infancy with severe pulmonary regurgitation; patient with coarctation repair in infancy with large aortic aneurysm) could have avoided development of severe symptoms leading to a bad outcome. Some loss to specialised follow-up can be physician-related, with the similar assumption that patients are stable, whereas, the anticipated complications may not be actively investigated for. Specialised ACHD has a particularly important role in the management of pregnant women, where pre-conception planning and recommendations, along with high risk obstetric care may minimise maternal and foetal complications. There are deficiencies in the current CHD services in Australia and across the world. These include poor transition of care, insufficient numbers of ACHD trained specialists/surgeons and allied health staff, along with funding and governmental issues that may limit optimal care due to ever-increasing patient numbers, prolonged length of stay for complicated patients and new and expensive medical technologies (e.g. catheter-based valve replacements). Improvements in effective transitioning of care and tracking of paediatric CHD patients is vital. Exposure of ACHD in medical and cardiology training may improve physician awareness of the issues faced by these patients. Lastly, improved funding of care for ACHD patients and ACHD centres is likely to become a major issue in future years as the number of adults with CHD continues to increase.

References

1. Le Gloan L et al. Recent advances in adult congenital heart disease. Circ J 2011;75:2287-95

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