Anaesthesia for paediatric diagnostic and interventional cardiological procedures

Revalidation FOR ANAESTHETISTS
RCA Revalidation matrix
Matrix reference 2D02 3D00

Syed Mohsin Qureshi BSc MBBS MD FCARCSI
Kuberan Pushparajah BMBS MRCPCH
Dan Taylor MB ChB MRCPCH FRCA

Key points

Children presenting for cardiac catheterization may have complex pathophysiology and multiple co-morbidities.

Maintaining haemodynamic stability during the procedure is crucial in obtaining meaningful diagnostic information.

Therapeutic interventions in the catheter laboratory include occlusion of patent ductus arteriosus, closure of atrial septal defects, balloon dilatation for valvular stenosis and stenting of narrowed vessels.

MRI is increasingly used for diagnostic imaging.

Anaesthetized children must be rendered apnoeic during cardiac MRI, as breath holds are often required for good quality imaging.

Syed Mohsin Qureshi BSc MBBS MD FCARCSI
Specialist Trainee
South East School of Anaesthesia
King's College Hospital, London, UK

Kuberan Pushparajah BMBS MRCPCH
Clinical Fellow
Department of Congenital Cardiology
Evelina London Children's Hospital
Guy's and St Thomas' NHS Foundation Trust, London, UK

Dan Taylor MB ChB MRCPCH FRCA
Consultant Paediatric Anaesthetist
Evelina London Children's Hospital
Anaesthetic Department
Guy's and St Thomas' NHS Foundation Trust
Westminster Bridge Road
London SE1 7EH, UK
Tel: +44 20 718 80654
Fax: +44 20 7188 2284
E-mail: dan.taylor@gstt.nhs.uk
(for correspondence)

Diagnostic cardiac catheterization was reported in the nineteenth century and interventional cardiac catheterization was first described by Rubio-Alvarez in 1954 for the treatment of pulmonary valve stenosis.[1] In some centres, MRI is increasingly used for diagnostic imaging. To ensure safety and quality images, the majority of these procedures in children require general anaesthesia. Cardiac catheterization may be challenging when dealing with complex congenital cardiac lesions. Good communication between the team members is essential, so that cardiovascular changes can be anticipated and minimized as far as possible. This includes the full team: anaesthetist and assistant, cardiologist, scrub team, radiographer, and a cardiac physiologist. It is a challenging and high-risk field of anaesthetic practice and requires consultant-led care by specialists in paediatrics and congenital heart disease (CHD).

Diagnostic cardiac catheterization

Diagnostic catheterization is becoming less popular with technological advances in non-invasive imaging such as cardiac CT and MRI allowing angiographic assessment. Paediatric cardiac catheter procedures are listed in Table 1.[2,3] Invasive studies are still necessary to directly measure intracardiac and intravascular pressures and to allow direct measurement of arterial, mixed venous, pulmonary venous and pulmonary arterial saturations and derive shunt fraction, flows and resistance (Table 2).[4,5] Dynamic investigations such as dobutamine stress testing and pulmonary vascular resistance studies (sometimes in conjunction with MRI) are also possible.

Endomyocardial biopsies and coronary angiography (and endosonography) are performed as part of routine surveillance after cardiac transplantation. Myocardial biopsies are occasionally used to diagnose myocarditis and cardiomyopathy.

Interventional cardiac catheterization

Interventional techniques

Valvuloplasty

A fluid-filled cardiac catheter is passed across the stenotic pulmonary or aortic valves and the pressure gradient assessed. This is exchanged over a guide wire for a balloon catheter, which is then inflated for a few seconds to split the fused valve leaflets. Balloon dilatation is repeated several times until an adequate reduction in gradient is achieved, ideally without severe valvular incompetence developing.

Pulmonary valvuloplasty has successfully been performed for many years. It is the treatment of choice for isolated pulmonary stenosis with a gradient of more than 50 mm Hg. Neonates with critical pulmonary stenosis are cyanosed, often requiring ventilation and a prostaglandin infusion to maintain duct patency. Desaturation occurs during balloon dilatation, but cardiac output can be maintained by a patent ductus arteriosus.

Critical aortic stenosis can be associated with severe cardiovascular collapse. Untreated severe aortic stenosis carries a high risk of sudden death. Aortic valvuloplasty presents a very high risk of haemodynamic instability and cardiac arrest from ischaemia and arrhythmias. Vasodilatation and hypovolaemia are poorly tolerated. Resuscitation drugs should be readily available to reverse haemodynamic compromise due to repeated occlusion of the aortic valve.

Septal defect closure

Atrial septal defect closure is the most commonly performed procedure. Trans-oesophageal echocardiography (TOE) is used to assess the margins of the defect and to aid X-ray-guided device placement. It is generally well tolerated, but, dislodgement and embolization of the device, impingement on the surrounding structures and

doi:10.1093/bjaceaccp/mku002 Advance Access publication 24 February, 2014

perforation of the heart or great vessels may occur. Ventricular septal defect closure is usually performed surgically on cardiopulmonary bypass but they can sometimes be closed with a percutaneous device.

Atrial septostomy

This procedure is performed to allow mixing of blood to improve oxygen saturation in cardiac lesions such as transposition of great arteries or single-ventricle circulations dependent on adequate mixing at atrial level. These children are often very sick with hypoxaemia, systemic hypotension, and metabolic acidosis. They will usually be receiving a prostaglandin (PGE1) infusion to maintain a patent ductus arteriosus.

A balloon-tipped catheter is passed from the right atrium through the foramen ovale and into the left atrium under trans-thoracic echocardiographic imaging. The balloon is then inflated and pulled across the septum to enlarge the septal communication. It is often performed several times until the atrial communication is large enough to allow free mixing of blood at atrial level. Complications include arrhythmias, perforation of the myocardium, embolization, and structural damage to the valvular apparatus.

Table 1 Paediatric cardiac catheter laboratory procedures

Indications	Procedure
Diagnostic	Defining cardiac and vascular anatomy
	Measuring haemodynamic pressures and shunts
	Pulmonary hypertension studies using nitric oxide
	Coronary angiography and endosonography
	Myocardial and endomyocardial biopsy
Interventional	Valvuloplasty
	Septal defect closure
	Atrial septostomy
	Angioplasty and placement of stents
	Percutaneous valve placements
	Closure of systemic to pulmonary shunts, e.g. patent ductus arteriosus
	Hybrid procedure
Electrophysiological studies	Conduction system mapping
	Radiofrequency and cryoablation
	Placement of pacemaker and ICD

Angioplasty and placement of stents

Angioplasty involves dilatation of narrowed blood vessels by a balloon-tipped catheter passed across the stenosed area. Occasionally, this is followed by endovascular stenting, for example in branch pulmonary artery stenosis, coarctation of aorta and superior vena cava obstruction. Stenting can involve passage of large catheters with risk of vascular damage, dislodgement and embolization of the stent.

Percutaneous valve placement

Severe pulmonary regurgitation or mixed pulmonary valve disease has traditionally required major surgery on bypass. The transcutaneous placement of pulmonary valves made from bovine jugular vein and titanium has transformed the management of these patients. Via a femoral venous sheath, the valve, mounted in a balloon-expandable stent, is threaded along a guide wire into the correct position under fluoroscopic and TOE guidance. The valve is then re-expanded to its final diameter to minimize any leaks or regurgitation.

Closure of systemic to pulmonary shunts

This is commonly performed outside the neonatal period to limit excessive pulmonary blood flow, for example, in patent ductus arteriosus. Helical wires are used to close small vessels; more complex devices are needed to occlude large vessels. There is a risk of device dislodgement and embolization.

Hybrid procedure

Surgical and endovascular techniques can be combined in certain circumstances, such as the first stage in palliation of hypoplastic left heart syndrome. It is usually performed soon after birth, with the aim of avoiding cardiopulmonary bypass in selected high-risk cases. This is a novel treatment performed in a few specialist centres. Hybrid procedures involve a sternotomy, followed by surgical

Table 2 Haemodynamic calculations performed during cardiac catheterization

Flows

Systemic flow$(Q_s) = \dfrac{\mathrm{VO_2}}{(Sao_{\mathrm{O_2}} - Smv_{\mathrm{O_2}})\,\mathrm{Cm}}$

Pulmonary flow$(Q_\mathrm{p}) = \dfrac{\mathrm{VO_2}}{(Spv_{\mathrm{O_2}} - Spa_{\mathrm{O_2}})\,\mathrm{Cm}}$

$\mathrm{VO_2}$, oxygen consumption; $Sao_{\mathrm{O_2}}$, aortic saturation; $Smv_{\mathrm{O_2}}$, mixed venous saturation; $S\,pv_{\mathrm{O_2}}$, pulmonary venous saturation; $S\,pa_{\mathrm{O_2}}$, pulmonary artery saturation; Cm (oxygen content)$=S\,p_{\mathrm{O_2}} \times$ Hb (in g dl^{-1})$\times 1.34 \times 10 + (Pa_{\mathrm{O_2}}$ mm Hg $\times 0.003)$

Resistances

Pulmonary vascular resistance (PVR) $= \dfrac{\mathrm{PAP} - \mathrm{LAP}}{Q_\mathrm{p}}$

Systemic vascular resistance (SVR) $= \dfrac{\mathrm{AoP} - \mathrm{RAP}}{Q_\mathrm{s}}$

PAP, pulmonary artery pressure; LAP, left atrial pressure; AoP, aortic pressure; RAP, right atrial pressure

Shunt fraction

Pulmonary to systemic flow ratio $(Q_\mathrm{p}{:}Q_\mathrm{s}) = \dfrac{Sao_{\mathrm{O_2}} - Smv_{\mathrm{O_2}}}{S\,pv_{\mathrm{O_2}} - S\,pa_{\mathrm{O_2}}}$