Southern African Journal of Anaesthesia and Analgesia 2018; 24(3)(Supplement 1)

South Afr J Anaesth Analg
ISSN 2220-1181 EISSN 2220-1173

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Anaesthesia and the cardiac catheterisation laboratory

M E A Kemp

Department of Anaesthesia, Chris Hani Baragwanath Academic Hospital, University of the Witwatersrand
Correspondence to: meakemp@mweb.co.za

Introduction

Cardiovascular disease (CVD) is the most common cause of death globally.[1] In 2015, 31% of all deaths worldwide were due to CVD, and of these deaths three quarters occurred in middle and low-income countries. Therefore, there are many patients who will require diagnostic and interventional procedures in Cardiac Catheterisation Laboratories (cath labs). Hackett[2] estimates that 700 to 800 patients per million of the population will require a session in a cath lab per year.

While the cath lab is primarily the domain of the cardiologist, radiologist or vascular surgeon, many of the patients also require anaesthesia services because of their age, medical condition or because of the complexity and length of the interventional procedures that are now being performed.

Anaesthesia challenges in the cath lab

The cath lab provides a demanding and unique environment for the anaesthetist and is an excellent example of practising anaesthesia at a remote site in unfamiliar surroundings.

Anaesthesia rooms and recovery units associated with labs are often rudimentary or non-existent and operating theatres and post-anaesthesia recovery units can be some distance from the lab, although there is now a trend for the development of hybrid cath lab/operating rooms, where hybrid catheter based and surgical procedures or rescue surgical interventions can be undertaken.

The population of patients presenting to the cath lab is heterogenous and ranges from the critically ill neonate to the critically ill geriatric patient, and the anaesthetist must be able to manage patients with multiple associated medical conditions and unstable haemodynamic states. The anaesthetist may now also be called upon to provide both anaesthesia and to participate by providing trans-oesophageal echocardiographic guidance for the interventionalist during the procedure.

The anaesthetist must also have adequate knowledge of the environment of the cath lab as well as about the risks of fluoroscopy and the injection of contrast dyes. They must be able to communicate with personnel and colleagues outside of an operating theatre, who may not be familiar with anaesthesia.

The environment of the cath lab

Cath labs consist of a procedure room and a shielded control room. Most labs are crowded with equipment relatively unfamiliar to anaesthetists and the anaesthesia workstation often is hedged behind the fluoroscopic arms, severely limiting access to the head and the intravenous lines of the patient and potentially exposing the anaesthetist to radiation.

There is often limited help from staff and colleagues who are unfamiliar with the requirements of anaesthesia. Whatever anaesthetic technique is used, it is mandatory that drugs and equipment for resuscitation, including suction, intubation and ventilation equipment, and external defibrillation are available at all times and that patients are monitored with a minimum of the standard American Society of Anaesthesiologist (ASA) monitors.

General problems with anaesthesia in the cath lab include lifting/transferring unconscious patient and placement of patients on a narrow, poorly padded table for prolonged periods. This requires attention to pressure points and positioning. Many procedures require positioning of both hands above the head out of the way of the chest; care must be taken to avoid hyperextension injury to the brachial plexus.

Cath labs require climate control for functioning of the imaging equipment and are usually kept at a cooler temperature than operating theatres so that active warming of patients is usually required.

Radiation hazards [3,4]

Exposure to ionising radiation causes significant adverse biological effects. Patients directly exposed to the radiation beams can experience skin burns and dermal necrosis. There is also an increased risk of cataract formation.

Exposure to excessive amounts of Low-Dose Ionising Radiation (LDIR) is associated with an increased incidence of cancers, particularly of the brain, skin and thyroid, as well as an increased incidence of birth defects and infertility. In a study of adults[5,6] with congenital heart disease who had been exposed to ionising radiation as a result of cath lab procedures, cumulative exposure was independently associated with an increased risk of cancer, with the incidence of cancer in this series of patients under the age of 65 years being 15.3 %.

The Sievert is the SI unit measuring the biological effects of ionising radiation, replacing the REM (Roentgen equivalent (for) man). There are no established guidelines available regarding the maximum amount of radiation exposure for anaesthetists. However, according to the EU International Commission on Radiological Protection, occupational exposure[5] for personnel exposed to ionising radiation should be limited to 20 mS per year, averaged out over five years, with an annual maximum limit of 50 mS. A lifetime limit of 10 mS x age (years) is recommended. Normal background radiation is approximately 0.5 mS per year.

In a study of Electrophysiology lab staff,[7] mean exposure to radiation doubled but remained well under the annualised recommended dose limits. In studies of cath labs, the average exposure to radiation was 2–4 mS per year.

Methods of limiting exposure to ionising radiation

It is standard for all staff exposed to ionising radiation to wear two dosimeter badges so that levels of exposure can be measured; one badge should be placed under the lead apron and one should be placed on the collar, exposed to the environment.

Shielding

Protective lead lined aprons, thyroid collars, and hats should be worn always. Protective eyewear is not mandatory for anaesthetists, although it might well still be prudent to use these. Operators working directly in the line of the beams should wear shielding gloves as well. Even with these measures, 18% of active bone marrow is exposed to the environmental radiation.

Most exposure of staff to radiation occurs because of scatter from the surface of the patient in the area next to the beam, and this is not always adequately shielded by aprons. The use of acrylic shields and stands in the correct positions to absorb the scatter should be used.

The intensity of radiation is proportional to the square root of the distance away from the source, so removal to as reasonable a distance as possible is advisable during exposure. Anaesthetic modifications to allow for this involve using longer breathing circuits and intravenous lines and the use of Total Intravenous Anaesthesia (TIVA) (rather than the need for bolus dosing of drugs).

The ALARA principle (As Low As Reasonably Achievable) refers to deliberate techniques to minimise the amount of ionising radiation that both the patient and the lab staff are exposed to.

Contrast Dyes

The non-ionic agents (Iohexal, Iopamidol, Ioxilan) used now have a better safety profile and less potential for allergic reactions than the older ionic agents, but the risk of Contrast Induced Nephropathy (CIN) remains, particularly during prolonged interventional procedures and those with pre-existing abnormal renal function. Limiting the dose of contrast and ensuring adequate hydration are the only proven methods of preventing CIN.

Anaesthesia in the Cath Lab

Cardiac procedures in the cath lab can take from one to six or eight hours. The procedures are relatively non-stimulating and result in minimal postoperative pain. Pain occurs with puncture of vessels, percutaneous insertion of large bore sheaths, dilation of vessels and during radiofrequency ablation.

Most, if not all, procedures do require the patient to lie flat; to cooperate with requests (e.g. breath-holding) and remain relatively immobile for prolonged periods.

A wide range of anaesthetic techniques is used. Anaesthesia can be limited to injection of local anaesthetic by the operator at the side of catheter insertion, combined with either light or moderate sedation, which is often administered by non-anaesthesia personnel. The JCAHO (Joint Commission on Accreditation of Healthcare Organization) recommends that sedation practice should be supervised by the anaesthesia department.[3]

There are several indications for moderate to deep sedation or general anaesthesia in the cath lab that require the services of the anaesthetist. These include:

1. Patients with haemodynamic or respiratory instability that requires intervention (for example, the use of inotropes or intra-aortic balloon pumps), or who are unable to lie flat or cooperate with the procedure.
2. Children.
3. Anxious or claustrophobic adults.
4. Patients with congenital heart disease with complex anatomy who require prolonged diagnostic or interventional procedures.
5. Procedures that require the use of transoesophageal echocardiography(TEE); patients requiring percutaneous valve ballooning or replacement, left atrial ablation, trans-septal punctures or testing of intracardiac defibrillating devices (ICD).

Anaesthesia techniques

There is no strong evidence favouring one anaesthetic technique over another and all types of drugs and anaesthetic techniques have been described for patients in the cath lab. Techniques range from Monitored Anaesthesia Care (MAC), light to moderate to deep sedation, regional anaesthesia (the beneficial effects on lower limb vascular patency associated with the use of epidural techniques is noted) and general anaesthesia using both inhalational and TIVA.[8,9]

Whatever technique is used, the anaesthetist must be aware of the haemodynamic consequences of the underlying cardiac disease as well as of associated comorbidities that occur commonly, such as diabetes, hypertension, lung disease and cardiac failure.

The aim of anaesthesia is to produce an immobile, comfortable patient while minimising the effects of anaesthesia on the cardiovascular system. Apart from being a desirable anaesthetic aim, changes in systemic and pulmonary vascular resistance caused by drugs, ventilatory techniques and oxygenation can interfere with measurements of pressures in diagnostic caths and can affect the conducting system of the heart, interfering with electrophysiological studies.

Heparin is given during all intravascular procedures; during cardiac caths the Activated Clotting Time (ACT) is usually maintained between 200 and 300 seconds (normal ACT approximately 80 seconds).

Complications

Apart from complications occurring as a result of anaesthesia itself, there are specific complications that can occur during cath procedures and these should be anticipated.

Major vessel or cardiac perforations, leading to hypovolaemic shock, cardiac tamponade or pneumothoraxes are possible and myocardial ischaemia with refractory hypotension can be precipitated.

Cardiac arrhythmias, usually self-limiting are common and often precipitated by direct stimulation of the myocardium by catheters. They are usually self-limiting but do sometimes require synchronised cardioversion.

Embolic phenomena such as strokes can result from intravascular blood clots; devices and coils are also reported. Excessive bleeding from puncture sites can occur in the presence of anti-coagulation.

Examples of typical procedures performed in the cath lab

1. Diagnostic coronary angiography, percutaneous intervention(PCI) (balloon angioplasty and coronary stenting)

These patients are generally adults and the procedures are usually performed under mild sedation with local anaesthesia. Anaesthesia is usually only required in cases of haemodynamic instability or respiratory distress – usually the result of extensive myocardial ischaemia, infarction or cardiac failure. Sedation with intubation and ventilation, as well as support of the circulation with the use of inotropes, vasodilators and fluids is sometimes required. Intensive monitoring by way of intra-arterial pressure monitoring and central venous access are recommended in these cases. While in emergencies, the cardiac sheaths as placed by the operator can be used to give drugs, it is advisable to have separate arterial and venous access to that of the interventionalist so that treatment is not interrupted during the procedure.

2. Balloon valvotomies and valve stents

Valvotomy of stenotic mitral, aortic and pulmonary valves is sometimes indicated in children, young adults or pregnant patients, either as definitive treatment or as a bridging measure to later open surgery. In general terms, a balloon catheter is placed across the valve and inflated to tear the valve leaflets and thus relieve the stenosis. These patients often require general anaesthesia because of their cardiovascular symptoms and for the use of transoesophageal echocardiography.

For aortic valve ballooning, overdrive pacing is usually used at the time of balloon inflation to mitigate the effects of the sudden, massive increase in systemic vascular resistance accompanying the complete occlusion of the valve. A temporary pacemaker is inserted and ventricular pacing at high rates (180–200 bpm) is instituted during the ballooning in order to prevent catastrophic acute left ventricular failure. A similar overpacing technique can also be used during balloon valvotomy of the pulmonary valve to prevent the aptly named syndrome of the 'suicidal right ventricle'.

As the tearing of the valve cannot be controlled, balloon valvotomy generally results in some degree of valve regurgitation. On occasion this can be severe, and the anaesthetist must therefore be able to cope with a patient who has sudden onset mitral or aortic regurgitation.

3. TAVI (Trans-catheter aortic valve implantation)

TAVI was introduced in 2002 and uses a retrograde transfemoral or a transapical approach (via a mini-thoracotomy) to insert a 'Sapien' or a 'Corevalve' stent. This was initially introduced for patients with severe aortic stenosis who had contra-indications to open heart surgery (and so were usually either old or very sick.) This approach is associated with a lower mortality and less cardiac symptoms post procedure and at one year, but with a greater incidence of major vascular complications and a trend to an increased incidence of strokes as compared to conventional open valve replacements.

Anaesthetic management of TAVI:

Many patients require general anaesthesia, usually with intubation and ventilation and invasive monitoring. Blood must be available because major haemorrhage can occur, and the feasibility of rescue open valve replacement should be considered.

Trans-ventricular pacing wires are inserted to provide overdrive pacing during stent deployment.

Haemodynamic instability often occurs around the time of deployment of the stent.

TEE is usually used to guide stent insertion, to identify problems such as occlusion of the coronary artery orifices, para-valvular leaks, damage to the mitral valve or pericardial tamponade.

Other valve replacements/stents that are currently being used are the 'Mitraclip' mitral valve stent for use in patients with mitral regurgitation and a pulmonary valve for patients with pulmonary stenosis.

Para-valvular ring leaks that occur post open surgical valve replacement can sometimes be addressed in the cath lab using '*Amplatzer*' type devices. This obviates the need for repeat open surgery. These patients often require general anaesthesia for this because of the length of the procedure and the requirement of TEE control.

4. Pacemaker insertion and ICD insertion

These procedures are usually performed under local anaesthesia with mild sedation, but when the anaesthetist is called to the cath lab in connection with one these patients, it is usually because the patients are ill with multiple comorbidities and heart failure.

Patients with refractory cardiac failure or life threatening ventricular arrhythmias may require insertion of permanent pacemakers for Cardiac Resynchronization Therapy (CRT), defibrillating pacemakers/ICDs or Left Ventricular Assist Devices ("Impella"). These are often performed under local anaesthesia but testing of defibrillators is usually done under anaesthesia or deep sedation.

5. Electrophysiological (EP) studies for tachyarrhythmias and ablation procedures

Many of these procedures are performed under mild or moderate sedation, although there is some evidence that atrial ablation procedures for atrial fibrillation are more successful when performed under general anaesthesia.

Of importance is the requirement for immobility and shallow breathing/breath holding at times during mapping of conduction pathways; care must be taken that if deep sedation is given, this does not result in airways obstruction and increased respiratory effort. Pain occurs during radiofrequency ablation.

When providing general anaesthesia in the EP lab, it is important to have knowledge of the effects of the commonly used anaesthetic agents on cardiac conduction. Propofol shortens the Qtc but does not increase Qtc dispersion and so does not increase susceptibility to ventricular arrhythmias.

In a small series of patients with Wolf-Parkinson-White syndromes[9] no clinically significant effects on sino-atrial node function, atrio-ventricular node or accessory pathway conduction was noted.

In pigs, remifentanil depresses SA node function and does not affect intra-atrial, Av conduction of QT intervals. Dexmedetomidine inhibits both SA and Av node function; increases the PR interval and potentially inhibits the induction of tachyarrhythmias.

6. Left Atrial Appendage Occlusion

The '*Watchman*' left atrial appendage occlusion device is used in patients who have non-rheumatic atrial fibrillation and who cannot be anti-coagulated, for prevention of in-situ thrombus formation. Occlusion devices are placed under TEE guidance and therefore require general anaesthesia.

7. Diagnostic and interventional caths for congenital heart disease

Patients with congenital heart disease often have a completely different disease profile to other patients presenting to cath lab. Many are infants or children who usually require either deep sedation or general anaesthesia for both diagnostic and interventional procedures. The incidence of cardiac arrest and death in this population group is 0.08% for diagnostic procedures and 0.5% for interventional procedures.[10] Those patients with supra-systemic pulmonary artery hypertension are at particular risk.

Patients with intra-cardiac shunts from both the left to the right side of the heart, or from the right to the left side of the heart are at risk from paradoxical intravenous air embolism to the cerebral circulation and care must be taken to thoroughly 'de-air' any lines and avoid injection of any amount of air into the circulation.

Diagnostic catheterisation and device closure of patent foramen ovale, (PFO), atrial septal defect (ASD), ventricular septal defect (VSD) and patent ductus arteriosus(PDA):

Most patients with significant atrial or septal defects or PDAs with 'left to right' shunts will require diagnostic cardiac catheterisation in which pulmonary and systemic pressures are measured; the reversibility of pulmonary hypertension is assessed and the shunt is quantified. As many of these patients will be small children who cannot cooperate with the procedure, either deep sedation or general anaesthesia is usually required.

Many types of anaesthetic techniques have been successfully used. The combination of inhalational agents such as sevoflurane and combinations of drugs such as propofol, ketamine, fentanyl, midazolam and dexmedetomidine are described.[10] There is some controversy regarding the effect of ketamine because of sympathetic stimulation and its effect on pulmonary vascular resistance. The drug is widely used and the objections appear to be more theoretical than practical.

The effects of oxygen concentration and ventilation and anaesthetic agents on pulmonary pressures should be kept to a minimum. When using deep sedation, respiratory depression or airway obstruction must be avoided because of the effects of hypercapnia and hypoxia on pulmonary artery pressures. Inspired oxygen concentration is usually kept between 21 and 25% in order not to complicate measurements of intra-cardiac and arterial pressures. Reversibility of pulmonary vascular resistance is usually measured after a period of ventilation with 100% oxygen.

Lesions with suitable anatomy can be closed with devices of the '*Amplatzer*' type or by coil embolisation. These procedures usually require general anaesthesia in children and the anaesthetist must be aware of potential complications of these procedures such as device embolisation, worsening of right heart failure, arrhythmias (usually supra-ventricular tachycardias) or pulmonary hypertensive crises.

Coarctation of the aorta

Patients with recurrent or previously undiagnosed coarctation of the aorta are candidates for stenting in the cath lab as the presence of collaterals around the aorta present a significant risk to open repair. These patients often have poorly controlled hypertension, with target organ damage (left ventricular hypertrophy, diastolic dysfunction, renal disease). The procedure entails insertion of an aortic stent which requires a brief period of obstruction to thoracic aortic flow as the stent is deployed, significantly, albeit transiently, increasing systemic vascular resistance similar to that of deployment of stents used in the treatment of aortic aneurysms.

Patients with cyanotic congenital heart disease and Fontan type circulations

Not all patients with congenital cyanotic heart disease will require cardiac catheterisation prior to surgery. Contrast angiograms of the pulmonary arteries are sometimes required because of the presence of hypoplasia or aneurysmal dilations of the pulmonary vessels. Stenting of stenosed pulmonary arteries pre or post-surgical repair can be performed in both Tetralogy of Fallot and Fontan patients. Device closure of fenestrations between the superior vena cava and the right atrium in Fontan patients can improve their oxygen saturations.

Neonatal Emergencies

Neonates presenting to the cath lab often have life-threatening conditions such as transposition of the great vessels with an intact atrial and ventricular septum for atrial septostomy, or critical pulmonary valve stenosis for valvotomy. They generally require intubation, ventilation and circulatory support.

Conclusion

The cath lab provides a demanding environment for the anaesthetist. Knowledge of a wide array of cardiac conditions in both adults and children is required, as well as knowledge of the specific procedures undertaken and of the risks of radiation. Increasingly, the anaesthetist is now an integral part of the interventional team, responsible for anaesthesia, haemodynamic and ventilatory support of the patient and for echocardiographic guidance of procedures.

References

1. World Health Organization. Fact sheets. 2018. Available online: http://www.euro.who.int/en/media-centre/fact-sheets
2. Hackett D. How Many Cath Labs Do We Need? Heart. Aug 2003(2);89(8): 827-9.
3. Hamid A. Anaesthesia for Cardiac Catheterization Procedures. Heart Lung Vessel. 2014:6(4):225-31.
4. Thangavel P, Muthukamar S, Kathekeyan B-B, et al. Anaesthetic Challenges in Cardiac Interventional Procedures. World J Cardiovasc Surg. Nov 2014;4:206-216. Available online: http://dx.doi.org/10.4236/wjcs.2014.411030
5. Ladouceur VB, Lawler PR, Gurvitz M, et al. Exposure to Low Dose Ionising Radiation From Cardiac Procedures in Patients with Congenital Heart Disease. Circulation. 2016;133:12-20. doi: 10116/CIRCULATIONAHA.115.019137
6. Cohen S, Liu A, Gurvitz M, et al. Exposure to Low Dose Ionising Radiation from Cardiac Procedures and Malignancy Risk in Adults with Congenital Heart Disease. Circulation. Dec 2017;21:pii. CIRCULATIONAHA.117.029138 doi: 10116`/CIRCULATIONAHA 117.029138
7. McAshley, E. Anaesthesia for Electrophysiological Procedures in the Cardiac Catheter Laboratory. BJA Educ, Crit Care Pain. Oct 2012;12(5).
8. Braithwaite S, Kluin J, Buhre W, de Waal EEC. Anaesthesia in the Cardiac Catheterization Laboratory. Curr Opin Anaesthesiol. August 2010(5);23(4): 507-12.
9. Hayman M, Forrest P, Kam P. Anaesthesia for Interventional Cardiology. Available from: http://doi.org/10.1053/j/jvca.2011.09.004
10. Shook DC, Savage RM. Anaesthesia in the Cardiac Catheterization Laboratory and Electrophysiology Laboratory. Anaesthesia Clin. Mar 2009;27(1): 47-56. Available from: http://doi10.1016/j.ancli.2008.10.011