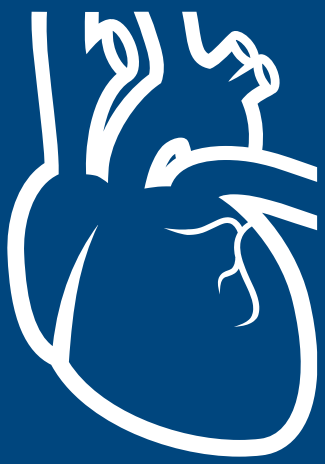
ISCAP Interventional Society for Cathlab Allied Professionals



Cardiac Catheterisation

Manual - Module 3

EDUCARE

ISCAP Interventional Society for Cathlab Allied Professionals

The ISCAP Catheterisation Manual

Endorsed by
The South African Society of Cardiovascular Intervention (SASCI)
The Society for Cardiovascular Angiography and Interventions Foundation (SCAI)

SASCI

South African Society of Cardiovascular Intervention

SCAI

The Society for Cardiovascular Angiography and Interventions Foundation

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While every effort has been made to ensure accuracy of the information in this book, development of new knowledge and understanding of cardiology as a whole may render obsolete some of the information and opinions expressed herein. Health care practitioners must always assess the best clinical context in which to be taken and make judgements regarding technique, diagnosis and therapy accordingly. The author, publisher, editors or others involved in the production of this book assume no liability for any injury or consequence of actions resulting from the use of material contained within.

Should one notice unintentional errors, or any information that could improve the content within, please connect with the ISCAP members within the editorials to suggest these improvements.

Foreword

Where once we were a murmur, we now have the opportunity to find our own rhythm and become the true heart of the cath lab.

Though the quality of South African Cardiology has always been on a par with the rest of the world, the training of professional nurses, technologists and radiographers (Allied Professionals), in the highly specialised field of cardiovascular intervention has been neglected. Our country has lacked guidelines that describe the requirements for a cardiovascular interventional laboratory to be managed successfully. There continues to be no official course to provide credentialing in the subject to the registered nurse.

The national Interventional Society of Cath Lab Allied Professionals (ISCAP) aims to uphold a high standard of cardiovascular interventional laboratory practice and improve the standing of the nursing and allied professional working within that environment. By these means our members will gain recognition as important participants in patient management within the cardiovascular interventional laboratory.

This second edition of the Cath Lab Manual is the continuation of this process. The Manual has been written for all those who work in the cardiovascular interventional laboratory, both as an introductory aid for the novice and as a reliable reference for the experienced practitioner.

By ensuring that educational material such as this is available on line and in hard copy , we are enabling ourselves to assume greater responsibility for our staff's development and our own job satisfaction. We also hope that the overall morale will also be enhanced.

CPD points will be attainable for those who wish to complete the questions at the end of each Chapter. There will also be a component whereby we can share information and experiences on line.

We need to equip staff with the knowledge and specific skills necessary for invasive physiology and anatomical assessment, also for the diagnosis and management of coronary and structural disease.

We trust you will find the Manual helpful. We look forward to hearing your comments and criticisms, so as to contribute to the greater value of this ongoing process of sharing information and thus learning from each other.

If you want to go quickly, go alone. If you want to go far go together

~ African proverb

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All new content is to be reviewed as it is created and thereafter approved by the panel below. This is for all digital and print versions.

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Contents

Module 3

3.1 Radiation and Contrast Agents

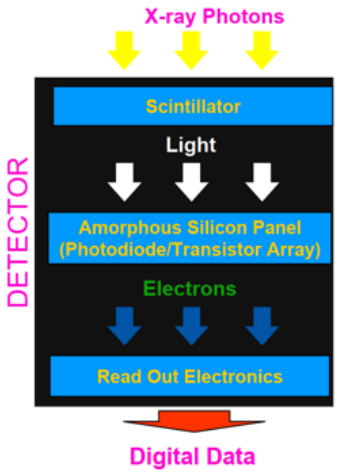
The cardiac catheterisation laboratory is a potentially hazardous area if proper safety measures are not followed. There is a constant risk of exposure to radiation, blood and body fluids and infectious diseases. This chapter will focus on radiation exposure and the use of contrast agents.

The main principle regarding radiation safety is to keep exposure to the patient and operator to a level as low as reasonably achievable (ALARA). The principle of ALARA is achieved by learning the various techniques at reducing radiation exposure and their possible effects on image quality.

The cardiac catheterisation laboratory consists of a patient support table, monitoring equipment and a floor and ceiling-suspended gantry that allows variable angulation of the x-ray beam through the patient. The patient support consists of an adjustable-height, flat-top table that can move horizontally and vertically within the x-ray beam. The function of the support equipment is to allow precise positioning of the radiographic imaging chain relative to the patient, in terms of both rotation (left or right anterior oblique) and skew (cranial or caudal) angulations. In some laboratories, a second complete imaging chain may be used to provide simultaneous viewing of cardiac structures from a separate angle. This is called a biplane imaging system.

RADIATION

Modern day angiography systems have evolved from the old image intensifier type, to the flat panel detector type systems. This has resulted in better image quality and enhanced performance of these systems. They enable sharper imaging of moving objects such as coronary arteries while optimising the x-ray beam to reduce radiation dose to patients and operators. The angiography system of today should have an imaging chain that can process this increased level of date from the detector to the benefit of the operators and ultimately the patient.



X-RAY TUBE

It is responsible for converting the electrical energy into x-rays. Of the electrical energy consumed by an x-ray tube, only 1% is converted to x-rays, the rest is converted to heat. Most x-ray tubes in a cardiac setup have two focal spots compared to a three focal spot configuration in a vascular setup. The tube has collimators fitted with a moveable beam.

FLAT PANEL DETECTOR

This is an amorphous material (Silicon) covered by a scintillating material, seated on a glass substrate, which absorbs the x-ray beam and converts tit to light. The light is converted by the Silicon to a charge that is read out by underlying electronic. In cath labs this readout has to be at a very high rate, 60 frames per second – paediatrics. Modern day detectors are 14 or 16 bit. A 16 bit unit provide a wider greyscale, more than 65000.

There is a cardiac dedicated unit and a larger unit used in the hybrid theatre for endovascular work.

IMAGING CHAIN

This is the conversion of the x-ray beam to the digital data and the ultimate display thereof on the monitors.

MONITORS

A cath lab has typically four to six monitors in use. Most of these monitors are used for the live images to display the anatomy of the patient. One of the monitors is used to monitor patient haemodynamics. It has become the norm for cath labs to utilise the medical grade large screens. This allows for the IVUS, IFR, FFR, OCT, TEE to be viewed during the interventional procedures.

Long term storage of images

All angiography systems are delivered with onboard storage capabilities. However, this storage space is not enough. All angio systems have the facility to write CD/DVD for long term storage of patient angio images. Many hospitals are making use of picture archiving systems (PACS). This allows for constant availability of images online and remote access thereof by operators.

There is still a need for pictures to be printed, as many patients enjoy the before intervention and afterwards pictures. Also, for those patients who live overseas or in Africa, the radiographer may still be required to print a CD/DVD.

The **image intensifier** electrically magnifies the image to allow accurate visualisation of the arteries or heart structures. The final path is to capture all these x-ray images and archive them. The logical format in which digital information is recorded is called DICOM (Balter: 1999).

X-RAYS

X-rays are generated when electrons travelling at a very high velocity are abruptly stopped. The x-ray emission is controlled electrically, and thus the system is inactive when power supply is off. An x-ray tube is a device where electrons can be produced, accelerated and stopped (Balter: 1999).

The production of X-rays

Inside the x-ray tube is a coil of tungsten wire (the filament) that is part of the cathode assembly. It operates like a light bulb: as the filament is heated by increasing the current, electrons are liberated. Exposure is determined by the relationship between the current (mA) and the amount of X-rays produced (Askari: 2011).

The acceleration of X-rays

Electrons are accelerated by introducing a high potential difference between the cathode and anode. The potential difference is measurable in kV. It is the level of kV that determines the quality of x-rays and defines the density of tissue that can be penetrated. Thus, the kV level must be increased in order to penetrate large volumes of tissue .

The stopping of X-rays

X-rays are formed from the energy released when the electrons are suddenly stopped as they collide with the anode. This energy is released in 99% heat and 1% x-rays. Although this process is not efficient, it is an effective way of generating a controlled quantity of radiation (Butler: 2007).

Scatter

Radiation travels in a straight line. Following interaction with an object, the course and quality of the x-ray is altered. This lower quality, attenuated radiation, is called scatter or secondary radiation. Primary radiation is the unattenuated beam (the x-ray before it interacts with an object). Scatter radiation is emitted from the patient in all directions. Most scatter will travel in the direction of the primary beam: i.e. towards the intensifier (Di Mario: 2011). The main source of radiation exposure for the operator and person standing at the head of the bed is scatter from the patient.

DEFINITIONS OF RADIATION UNITS:

Wagner (2000) defines the following radiation units:

Roentgen (R)

This is the measure of ionization to a specific point (exposure). One chest radiograph equals 3 – 5 mR.

Radiation absorbed dose (rad)

This is the amount of radiation energy deposited per unit mass of tissue. The amount of absorbed dose per given exposure depends on tissue type. For soft tissue, 1R = 1 rad; for bone 1R = 4 rad (i.e., greater absorption).

Radiation equivalent dose in man (Rem)

This is used to express the biological impact of a given exposure. For x-radiation, 1 rad = 1 Rem.

THE EFFECTS OF RADIATION

X-rays ionise matter: They remove an electron from the anatomic structure of the matter, which results in the breaking of atomic bonds. If all these bonds recombine exactly as they were, no radiation damage has ensued. However, broken atomic bonds can produce free radicals that are chemically reactive and capable of forming new bonds. This molecular disruption causes chemical changes and may produce biological cell damage (Baim & Grossman: 2000).

The deterministic effects of radiation are injury caused as a result of direct exposure, like dermatitis or cataracts (Balter: 1999).

The stochastic effects of radiation are the hereditary effects on reproductive cells. Neoplasms are classified as stochastic effects (Balter: 1999).

SIMPLE STRATEGIES TO MINIMISE EXPOSURE TO FLUOROSCOPY

- Mobile lead accessories:
  - Treat your lead apron with respect! Hang it up, do not sling it on the back of the chair. It may crack and you will be exposed to radiation
  - Make sure your lead apron is long enough and when you are turning away from the beam, ensure that a wrap-around apron is worn
  - Always wear a thyroid shield
  - Make use of radiation protective glasses and if available, a skull cap
  - Wear radiation protective sterile gloves if available
  - Ensure that your lead apron is a wrap around one, and that if it is of a lead composite that it has enough protection.

- Annual physical assessment of staff and blood investigations to be done to evaluate the detrimental effects of radiation exposure
- Keep screening times as low as possible. Less than 10 minutes for most procedures is acceptable. Only use fluoroscopy when looking at the screen
- The Inverse Square Law addresses the important concept that radiation dose drops rapidly by the inverse square of the relative increase of distance from the radiation source. It is important to stand as far back from the table or source as possible. Avoid standing at the head of the bed unless there is an emergency
- Spend less time acquiring images; the exposure is 10 times higher with acquisition mode than with screening mode. Keep acquisition runs short
- Cone down on the area of interest using the built-in shields in the x-ray equipment
- The radiographer must perform the screening and not the cardiologist according to South African law
- Keep the image intensifier as close to the patient as possible
- Keep the image magnification as low as possible
- Use slower panning, and provide good initial angiographic setup
- Use the lead screen that is mounted to the gantry for head & eye protection. Head exposure is more prominent during brachial accessed procedures
- Staff must choose times when fluoroscopy is not taking place to enquire after the well-being of the patient. This time is also used for drug administration
- In a right anterior oblique (RAO) position, the cardiologist is shielded from the patient by the image intensifier
- In a cranial projection, the cardiologist will be exposed to a high degree of scatter, and moving away from the beam is advised (Bashore: 2001)
- In a left anterior oblique (LAO) position, the cardiologist will receive the highest dose of radiation, and it is advisable that he moves away from the beam during imaging
- In an Antero-posterior (AP) projection, less scatter is produced and a high quantity of this is blocked by the image intensifier
- Only essential staff should be allowed in the catheterisation laboratory

Lead aprons should contain 0.5 mm-thick lead lining. When properly cared for, an apron can provide years of service. The lead lining can crack or tear, however, this is usually caused by careless handling or improper storage. Repeatedly throwing an apron over a chair may damage the lead lining. A hanging rack should be used to store lead aprons. To assess the integrity of the lead, aprons should be examined under fluoroscopy at least once a year

(Bashore: 2001). Documentation should be kept regarding the integrity of each apron.

Because of the nature of work in the catheterisation laboratory, personnel are not always able to maintain a frontal position to the x-ray beam. Wraparound lead aprons should be considered. Aprons should be long enough to cover the long bones (femur) and should extend to the knee or just below the knee (ACC: 1998).

The thyroid gland is particularly sensitive to ionizing radiation. A lead thyroid shield should be worn in the presence of ionizing radiation. Similar to lead aprons, the thyroid shields should be stored properly and checked periodically under fluoroscopy (ACC: 1998). Special lead skull caps are also available now.

A single x-ray exposure of 200 rad (R) can produce cataract formation. Glasses made of 0.5 – 0.75 mm lead-equivalent glass should be worn by all personnel exposed to radiation on a daily basis. Glasses with photochromic lenses offer two times the protection than regular glasses. Radiation-protection glasses must contain a wraparound side shield. Glasses with proper- fitting side shields are not only good radiation protection, but also provide protection from blood products splashing into the eyes (Einstein: 2007).

Radiation monitoring badges (dosimeters) should be worn by all staff when in the catheterisation laboratory. To ensure accurate readings, a badge should always remain on the person to whom it is assigned. Dosimeters should never be left lying on a counter or attached to a lead apron in an area where there is potential radiation exposure. When a dosimeter is not being used, it should be stored in an area away from potential radiation exposure. At the end of every month, the dosimeters are sent for analysis. A monthly exposure report indicates the staff member's exposure for that month. It is a good practice to post this information in the laboratory so that every staff member can monitor his or her own individual exposure (Wagner: 2000). The report should be reviewed by the institution's health and safety officer or nurse. The dosimeter should be worn on the inside of the apron on the torso of the health care professional and if no lead glasses or thyroid shields are worn, the dosimeter should be attached to shoulder area on the outside of the lead apron (Einstein: 2007).

PREGNANCY AND RADIATION

Special precautions need to be taken. The staff member needs to inform the Unit Manager and the Radiation Safety Officer. A special radiation monitoring badge, TLD, needs to be worn around the waist under the lead apron and weekly doses to be recorded. Eeckhout et al (2012) states that radiation safety limits for pregnant healthcare professionals are < 1 mSv for the entire pregnancy. Double thickness protective garments and specific maternity lead aprons should be worn and strict compliancy with accepted strategies to reduce radiation exposure.

The Hazardous Substances Act (Act 15 of 1973) and Regulations (No. R1332 of August 1973) stipulate that the radiation exposure of any health care professional should not exceed 20 miliSievert (mSv) per year and no more than 100 mSv per 5 year period.

The Department of Health permits the following radiation exposure:

- Lens of the eye: 150 mSv/year
- Skin: 500 mSv/year
- Hands & feet: 500 mSv/year

ANGIOGRAPHIC VIEWS

Coronary angiography provides a silhouette of the epicardial coronary arteries. The basic views, posterior-anterior (PA), left anterior oblique (LAO), right anterior oblique (RAO) with or without varying degrees of either cranial or caudal angulation, show the coronary arteries in orthogonal views, while minimising interference by other structures, such as the spine and diaphragm. In general, cranial angulation is ideal for visualization of the distal portion of vessels, and caudal angulation is ideal for visualising the proximal portion of vessels (Freed: 1992).

During aquisition runs, the patient can be instructed to take in and hold a breath, especially in cranial angulations, to move the diaphragm out of the view.

Left coronary artery views

Kern (2011) differentiates in the following views to assess the left coronary artery:

- The first view of the left coronary system should delineate the course of the left main trunk. Most cardiologists prefer either a straight PA or a 20°
- RAO and 20° caudal angulations. The spine should be off the origin of the left main coronary trunk
- The 20° RAO, 20° caudal view is an ideal view for the proximal circumflex. In this view, while panning down the circumflex, portions of the LAD may also be visualised. The cardiologist can also visualise the left circumflex artery using a straight PA 30° caudal view

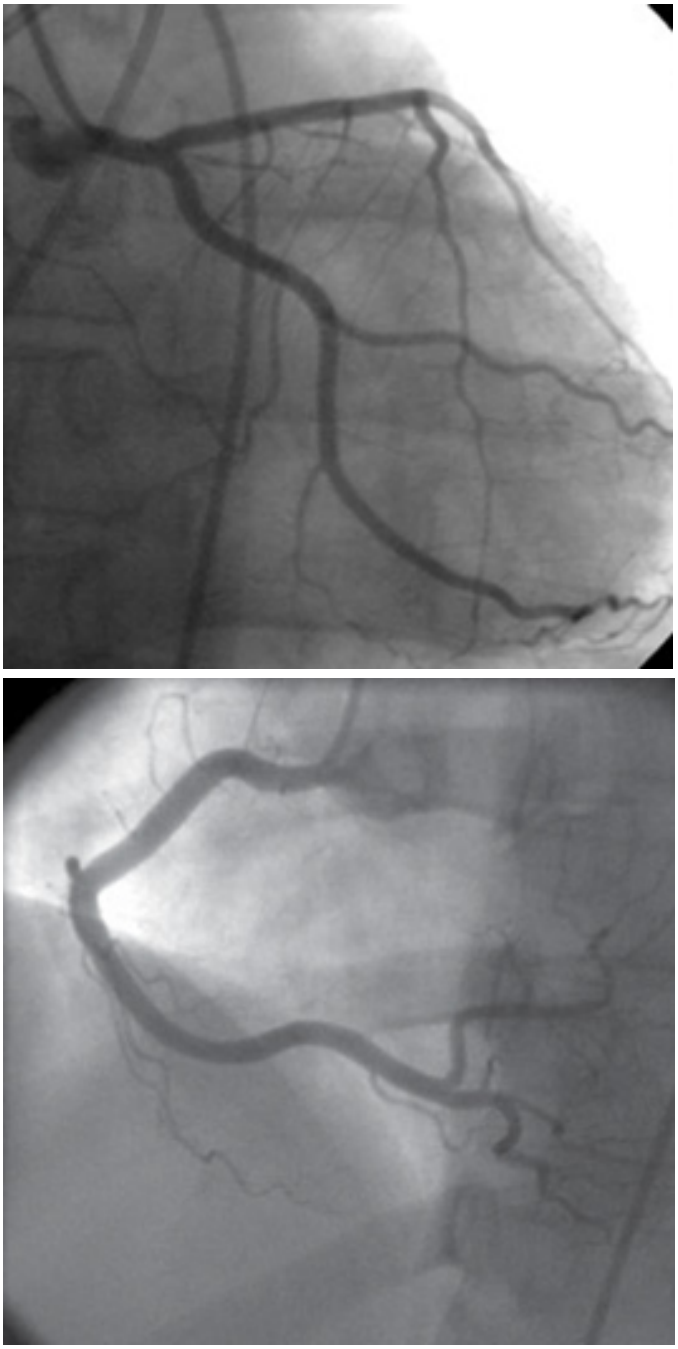


Figure 9.1: Vessel descriptions (angiographic views of normal vessels)

- A straight PA 40° cranial angulation view highlights the mid and distal portions of the LAD. To separate the diagonals from the LAD, a 30° RAO with a 25° to 30° cranial angulation is used. The diagonal is placed above the LAD in this view. Other useful views to separate the diagonals from the LAD are the 40° to 50° LAO and the 25° to 30° cranial views
- The proximal LAD and the left main artery can

also be visualised using the 45° LAO and 30° caudal view (spider view). The origins of the circumflex and the proximal diagonal arteries are also well visualised

- In cases where the mid-LAD needs to be visualised in additional views, (such as LIMA grafts) the straight lateral view 90° LAO can be useful

Right coronary views

Kern (2011) differentiates between the following views to assess the right coronary artery:

- The RCA is viewed either a straight RAO or LAO 35° – 40° view or a PA view with cranial angulation
- The 40° LAO view shows the ostium, proximal and mid portions best. The PDA and postero-ventricular branches can also be visualised
- The bifurcation of the RCA, PDA and the postero- ventricular branches are best seen in the 40° PA cranial view

Common Views

- **RAD (Right Anterior Oblique):** Image intensifier is above the patient on their right
- **LAD (Left Anterior Oblique):** Image intensifier is above the patient on their left
- **Cranial:** Image intensifier is closer to the patient's head

A summary of common angiographic views

Left Coronary artery	
20° RAO, 20° caudal	Left main & circumflex
40° PA cranial	LAD
45° LAO, 30° cranial	LAD & diagonal arteries
30° RAO, 30° cranial	LAD
45° LAO, 30° caudal	Left main, proximal LAD & proximal circumflex
Right coronary artery	
40° LAO	Proximal & mid RCA
40° PA cranial	Distal RCA (PDA & PV branches)
35° RAO	Proximal & mid RCA

Caudal: Image intensifier is closer to the patient's feet

- Lateral: Image intensifier is lateral to the patient
- Spider View: To view left main artery, bifurcation of circumflex and LAD arteries

CONTRAST AGENTS

Watson (2005) defines a contrast medium which can be a liquid, suspension or gas. When introduced into a compartment, the medium produces a change in the radiographic characteristics of that compartment. Two effects are possible: Either x-rays are attenuated or facilitated.

The more hydrophilic the contrast, the fewer side effects it will produce. Contrast agents are classified as high osmolarity or low osmolarity agents. Osmolarity is the quantitative expression of the capacity to attract water. Proportional to the iodine content is the viscosity of the contrast agents. Viscosity is the fluidity, and pre- warmed contrast is less viscous and thus will ease the injection thereof. Solubility of the contrast is essential in order to produce highly concentrated solutions. The higher the solubility of a contrast agent, the lower is the risk of crystallisation. Contrast agents contain sodium. Sodium reduces the risk of ventricular fibrillation during Coronary Angiography (Pepine: 1994).

Dosage of contrast agents

The safe dose volume of contrast is 3 – 4 ml/kg

TYPES OF CONTRAST AGENTS

First generation agents: Ionic high osmolarity agents

Have an osmolarity of 1400 – 2100 mOsm/kg water with an Iodine content of 300 mg/ml.

High osmolar contrast media (HOCM) provoke some discomfort in patients since the high osmolarity tends to make the vessel swell (water is attracted from the surrounding tissue), thereby inducing a feeling of heat.

Second generation agents: Low osmolarity agents

These agents are non-ionic or ionic preparates.

Non-ionic preparates

The osmolarity of these agents are 290 – 900 mOsm/ kg water. These agents have the same osmolarity as blood, but they have a high viscosity. These agents are routinely used for invasive procedures.

Table 17.1: Types of contrast agents available

Type	Trade & Generic name
IONIC HOCM	Urografin (Diatrizoate) - not used routinely
IONIC LOCM	Hexabrix (Ioxaglate) - not available
NON-IONIC LOCM	Imeron (Iomeprol) Omnipaque (Iohexol) Optiray (Ioversol) Ultravist (Iopromide)
NON-IONIC LOCM	Visipaque

Ionic preparates

The osmolarity of this agent is below 600 mOsmol/kg water and contains 150 mmol/l Sodium.

COMPLICATIONS ASSOCIATED WITH CONTRAST AGENTS

Kern (2011: 14-18) reported that in more than 300 000 patients the overall incidence of adverse reactions to contrast agents was 5%. Adverse reactions were found in 10-12% of patients with a history of an allergy and in 15% of patients with a reported reaction on previous contrast-mediated examinations. Apart from allergic reactions to contrast agents, contrast-induced nephropathy (with the predisposition to acute renal failure) is a feared complication of contrast agents (see Complications chapter later in this publication).

Patients with a known allergy towards contrast agents require pre-procedure prophylaxis. The standard regime for iodine allergy prophylaxis include: 30 - 60 mg Prednisone the night before the procedure and on the day of the procedure and 25 mg Phenergan administered at the time of call to the catheterisation laboratory (Uretsky: 1997) Solu-cortef 200mgms IV.

Freed (1992) differentiates between the following contrast-induced allergies: cutaneous and mucosal manifestations, smooth muscle and minor anaphylactoid responses and cardiovascular and major anaphylactoid responses. Patient may be nauseous and vomit, or restless and irritable.

Also, be alert should if the patient becomes breathless and the oxygen saturation drops.

- Cutaneous & mucosal reactions
  - Angioedema
  - Flushing
  - Laryngeal oedema
  - Pruritus
  - Urticaria
- Smooth muscle reactions
  - Bronchospasm
  - Gastro-intestinal spasm
  - Uterine contraction
- Cardiovascular reactions
  - Dysrhythmias
  - Hypotension (and shock)
  - Vasodilatation

Coronary Anatomy

RAO Projection

Helpful hints:

- The CFX always lies closest to the spine
  - Since the spine is towards the left of the image in an RAO projection, the CFX also lies to the left
- The LAD lies to the right
- The RCA resembles the letter "L"

Coronary Anatomy

Cranial & Caudal Angulation

- Cranial and Caudal angulations are very useful for spreading out foreshortened vessels
- Also helpful for spreading out bunched up, overlapped vessels in the proximal LCA or distal RCA
- When doing a PCI:
  - Cranial View: LAO/RAO Cranial for LAD treatment
  - Caudal View: LAO/RAO Caudal for Circumflex treatment

Coronary Anatomy

LAO Projection

Helpful hints:

- The "L Rule":
  - In the LAO, the LAD lies to the Left
- The CFX lies closest to the spine
  - Since the spine is towards the right, so too is the CFX
- The LAD reaches the apex and often curls around it – diagonal branches do not
- The RCA resembles the letter "C"

3.2 Radial Artery Access and Best Practices

Circulation: Cardiovascular Interventions
A Scientific Statement from the American Heart Association 2018.

Transradial artery access (TRA) for percutaneous coronary intervention (PCI) is associated with lower bleeding and vascular complications than trans femoral artery access (TFA), especially in patients with acute coronary syndrome (ACS). Use of TRA for coronary angiography and PCI may also be associated with improved measures of quality of life and reduced costs compared with trans femoral access (TFA).

CONCERNS ABOUT TRA IN ACS

Reperfusion Time and Procedural Success

Two of the most important determinants of outcome for patients with ACS relate to the time to reperfusion of an occluded artery and overall procedural success. Earlier studies reported a longer time to sheath placement and a longer door-to-balloon time with TRA, contemporary studies of TRA versus TFA have not demonstrated a significant difference in these times. There was also no difference in procedural success by access site among patients with ACS.

Access Site Crossover

Despite advances in devices and technique, access site crossover remains an important limitation of TRA. Real-world estimates of crossover rates have varied (4.6%-10%), but operator experience consistently predicts rates of crossover.

Some data suggest that use of left radial artery (LRA) over right radial artery (RRA) might help reduce crossover rates because of the lower prevalence of left-sided brachiocephalic tortuosity. Finally, crossover rates are also reduced with ultrasound guidance.

Cardio-thoracic surgeons do not want the LRA to be used as it reduces the arterial conduits available to them, should the patient require a CABG (coronary artery bypass graft)

Radiation Exposure

Randomized data has demonstrated longer fluoroscopy times with TRA procedures.

Studies have demonstrated that radiation exposure to both the patient and the operator is reduced with the use of lower-dose fluoroscopy and, at high volume TRA centres. There is also lower radiation exposure to the operator with additional radiation protection drapes.

Contrast Volume

Most studies have demonstrated no difference or lower contrast volume with TRA compared with TFA.

Doctor's learning the TRA approach may use more contrast as the catheter techniques required may prolong the procedure and thus radiation exposure is increased, and the amount

of contrast. It is important to also prepare the femoral artery to shorten procedure time, especially with a doctor who is learning.

Quality Measures and Patient Satisfaction

TRA has been shown to reduce time to ambulation and to improve patient quality-of-life metrics compared with TFA.

TRA is associated with less overall discomfort, body pain, and back pain. The ability to walk and use the bathroom made the TRA more popular. TRA was associated with more difficulty with self-care and routine activities that required the hand, whereas TFA was associated with more difficulty in walking.

Some vascular seals may cause the patient discomfort whilst walking for a few days.

Healthcare costs

Current data suggest that cost savings are derived primarily from lower vascular and bleeding complications, shorter average ICU and hospital lengths of stay, and minor differences in procedure costs.

RECOMMENDATIONS AND BEST PRACTICES FOR TRA IN ACS OPERATOR PROFICIENCY

The relative benefits of TRA over TFA are most pronounced in high risk patient subgroups such as those with ACS. Maintenance of adequate operator and centre volume is important in realising these benefits. Analysis of the TRA learning curve suggest that operator proficiency may reduce concerns about access site crossover, radiation exposure, contrast volume, delay in reperfusion time, and procedural success. Although suggested procedure volumes to achieve (>50 cases) and maintain (>80 procedures per year) proficiency have been proposed, many factors determine operator and centre expertise in TRA technique.

Predictors of PCI failure with TRA include: Patients > 75yrs old, female sex, previous CABG, cardiogenic shock, and short statue.

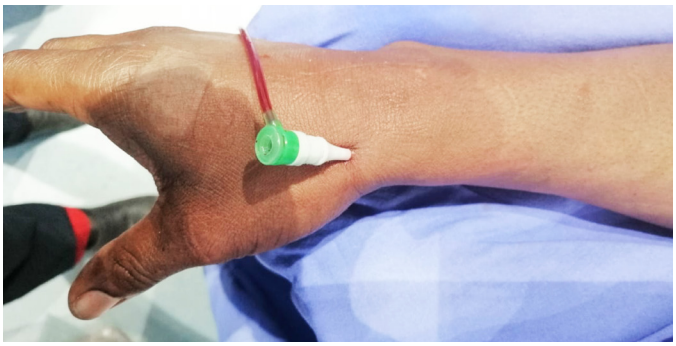
A radial-first approach is recommended in all patients, but a graduated level of centre and operator experience is recommended before TRA is pursued in patients with ACS.

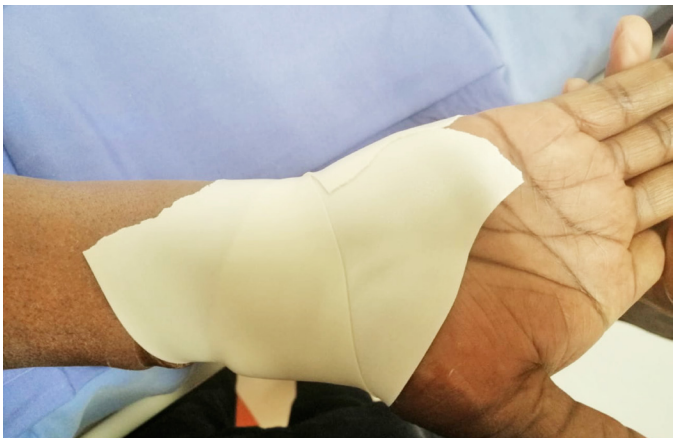
Noninvasive testing for collateral hand circulation (Allens or Barbeau test) does not predict adverse outcomes.

The choice between RRA versus LRA access is based on operator preference.

Ulnar artery access is an alternative among experienced operators, but it may be associated with a higher rate of discomfort or haematoma formation,

Ultrasound quidance facilitates vascular access,





Distal Radial artery access (Snuff-box)

in the setting of a weak pulse, hypotension, cardiogenic shock, or transulnar access.

Access can also be done via the right or left dorsal aspect of the thumb in the anatomic snuff box. Safety implications to the radial artery are unknown. Using the distal radial artery or snuff-box definitely reduces bleeding complications. Small framed people should be excluded as the artery is often smaller than the radial artery. Anatomical anomalies may also be encountered. Aftercare is more straigh forward as haemostasis is achieved faster.

It is best for the Interventionalist to start practising the distal access by selecting patients relegated to diagnostic angiograms.

Low-profile hydrophilic sheaths should be used to reduce patient discomfort and prevent RA spasm.

PHARMACOLOGY

Analgesia

Alleviating discomfort and anxiety is an important factor that helps prevent stimulation of central neural pathways and arterial vasoconstriction.

Administration of a low dose combination of fentanyl and dormicum has been shown to reduce patient discomfort, the incidence of RA spasm (2.6% versus 8.3%), and access site crossover (9.9%) versus 15.0%) compared to control. Administration of topical lignocaine may further reduce pain, but intra-arterial lignocaine is not effective.

O2 satuation must be checked before administration of these drugs, and constant monitoring for the duration of the procedure. O2 must administered via nasal or 40% mask and must remain for 2hours after the procedure. Fentanyl and dormicum must be administered slowly and the patient to be observed for chest rigidity.

Diazepam/Valium is effective in patients where the anxiety level is low or medium. The amount administered depends of the patient. It is important to check the O2 satuation and the pulse rate before administration. Usually, 2.5mg-5mgs Valium is adequate.

Administration of local anaesthetic 1-3mls of lignocaine 2% and provision of a warm environment can reduce patient anxiety and RA spasm.

Antispasmolytics

RA spasm can be minimised with the use of intra-arterial vasodilators. Nitrocine 100-200mcgms diluted into 10-20mls normal saline 0.9% is effective.

Verapamil 2.5-5mg, diltiazem 2.5-5gm or nicardipine 250-500mcgm (calcium channel blockers) reduce RA spasm and should be administered intra-arterially after sheath insertion and possibly with catheter exchanges or before sheath removal.

Do not administer these drugs if the patient has a poor left ventricular function (reduced ejection fraction), hypotension, cardiogenic shock, or severe aortic stenosis.

ADJUNCTIVE ANTICOAGULATION

Procedural anticoagulation, in combination with other procedural best practices such as maintenance of patent haemostasis (MOPH) is critical to preventing radial atetery occlusion (RAO).

Intraprocedural anticoagulation (unfractionated heparin 50U/kg up to 5000 u or comparable doses of clexane) should be administered to prevent clots in the sheath and catheter.

Control heparin dosage with ACT monitoring should PCI be undertaken.

We only administer the anticoagulant once the

catheter is in the ascending aorta , to avoid anatomic anomalies which can cause TRA failure. The most common cause for failure of TRA are anatomic anomalies.

Pain management is important to reduce the anxiety level and to assist with successful outcomes. Morphine may be required to control pain.

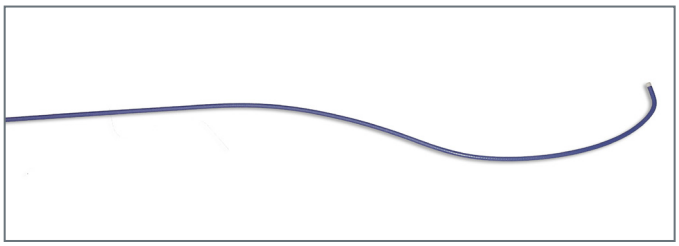
IV Paracetamol is also successful when the procedure is prolonged with many balloon and stent inflations.

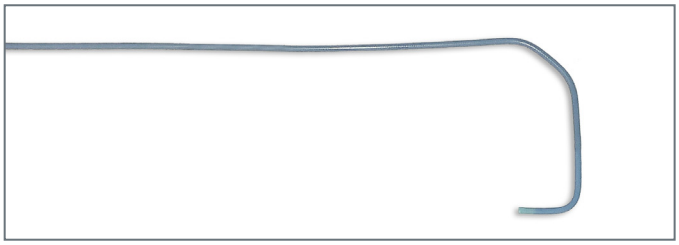
TRA WIRE AND CATHETER SELECTION

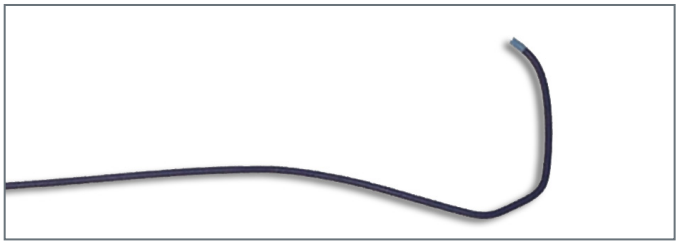
Navigation of RA, brachial Artery and Aorto-subclavian Artery Tortuosity

Variations in RA and aorto-subclavian anatomy may pose a challenge to wire navigation and catheter manipulation and increase procedure time.

- Use of a 1.5-mm-radius J-tip wire 0.35-in wire has multiple advantages over angle-tip hydrophilic 0.35-in wires, including minimized vessel wall contact and associated trauma and spasm, prefentially following the larger vessels and avoiding the smaller branches. Easier to use if the radial artery is small.
- It is always safer to screen the wire as it tranverses the brachio-cephalic artery into the ascending aorta. Complications of dissection/ perforation of the carotid or cerebral arteries can be avoided.
- Deep inspiration and use of stiff-bodied J wires for catheter exchanges may facilitate procedures in the presence of aorto-subclavian tortuosity.
- For difficult upper extremity anatomy, use of a 0.014-in wire with subsequent exchange to a 0.35-in wire may be considered.
- Balloon-assisted tracking and catheter-assisted tracking techniques may help navigate catheter traversing significant upper extremity vascular tortuosity or spasm.
- Operator TRA experience and preference largely dictate wire-choice, diagnostic and guiding catheter choice.
- TRA in cardiogenic shock is both safe and feasible and may be associated with reduced mortality.
- In high risk patients the cath lab team must be experienced and knowledgeable. Setting up for a radial procedure can take longer and the operator needs to be very skilful and experienced. The femoral artery needs to be prepared at the same time in case of IABP insertion or crossover for anatomical reasons.







Catheter Selection

Majority of operators still prefer:

Multiple catheter strategy: JR4 JL3.5 for the left coronary artery if RRA, JL4 for the left coronary artery if LRA.

Dedicated TRA catheters (eg, Kimny, Tiger, Jacky,

DxTerity, Ultimate) allow a single-catheter strategy to be used to engage the ostium.

Inadequate catheter support accounts for 7% to 17% of TRA PCI failures but this is less relevant as operator experience increases.

For the LCA : EBU, XB, Voda). AL1, AL2 Costello 1 & 2 - provide excellent back-up support.

For the RCA : JR4.

If the root of the aorta is dilated or has a "shepherd's crook" origin: AL 07.5 or IMA (3.0 or 4.0), XB –RCA, and Ikari left (3.5 or 4.0) guides. LCB also works in the RCA.

Operators should select the guide catheter that they find most comfortable.

Special patient populations

If a patient is expected to have CABG then it may be a suggestion to use TFA, as the cardio-thoracic surgeon may use the radial artery as a graft. It is important to remember that once the radial artery has been punctured the surgeon is unable to use it as a graft. The scarring from a radial artery puncture is apparent. It is therefore preferred that the same radial artery is used if possible should the patient return to the cath lab.

If the patient has had a prior CABG the LRA approach allows cannulation of the LIMA (left internal mammary artery). The IMA catheter or the VBI catheter can be used.

If there are bilateral mammary grafts then TFA may be a more suitable option. For grafts originating from the ascending aota, catheters with a longer curve (eg, MP1, Amplatz) may be needed to engage left sided grafts. Catheter extensions (eg, Guideliner, Guidezilla) can improve backup support and facilitate deep intubation during bypass graft interventions.

Cath Lab Observations : R) handed operators prefer RRA and left-handed operators prefer LRA. The ulnar artery can also be used successfully, and it is easier for a right handed operator to use the left ulnar artery! If the patient is very tall and has long arms ensure that you have 125cm length catheters available as 100cms will not reach the heart.

TRA SITE MANAGEMENT

Prevention and Management of RAO (Radial artery occlusion)

The most common complication of TRA is radial artery occlusion. Given the presence of dual circulation and extensive collateralization through the interosseous arteries to the hand, RAO after TRA is often not clinically apparent. However, best procedural practice requires techniques which allow for RA patency, thus protecting future vascular access.

Some patients with radial artery occlusion have reported **loss of functionality** in the hand. It is reported that it is more common when the ulnar artery is used.

Maintenance of patent haemostasis and full procedural anticoagulation, simultaneous prophylactic ulnar artery compression may be considered to prevent RAO. Applying the O2 saturation probe to the thumb will monitor blood flow to the hand. This can be applied post procedure, and checked regularly.

Simultaneous ulnar artery compression and systemic anticoagulation may also be used to treat RAO.

If a patient is a surgeon or totally reliant on his hands fully functioning for his work/ or other reasons, the TFA route may be preferable.

Management of TRA Site Complications

The incidence of major vascular complications after TRA is low.

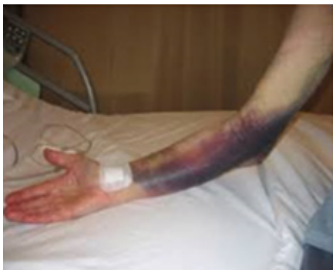
Reported complications include:

- Haematoma
- Perforation
- RA spasm
- Pseudoaneurysm
- Arteriovenous fistula
- Compartment syndrome
- Hand ischaemia
- Persistent post-procedural pain
- Neurological deficits
- Infection
- Aseptic granuloma

Radial artery haematomas are generally small and readily managed with manual compression, adjustment of compression band pressure, or repositioning of the compression band to a more proximal location.

Haematoma formation proximal to the access site (eg, forearm, upper arm) may indicate arterial perforation, usually of a side branch.

In cases of severe bleeding due to perforation during or post procedure, extrinsic compression with an elastic pressure bandage or blood pressure cuff inflated to subocclusive pressure can achieve haemostasis.



In rare cases when the bleeding is recognised very late or when haemostasis cannot be achieved due to arterial laceration, then surgical repair may be required and evacuation of the haematoma may be required to avoid compartment syndrome.

RA spasm that does not respond to conventional therapy (intra-arterial vasodilators, sedation, analgesia, forearm warming) and may require general anaesthesia or regional nerve block.

Inflating a BP cuff for a few seconds on the affected arm may also work to relieve the spasm.

Pseudoaneurysm can usually managed by manual compression alone. Throbin injection is not recommended because the patient with a short neck may disseminate thrombus to the hand.

An arterio-venous fistula is most often managed conservatively.

Indications for surgical repair include symptomatic arterial-steal phenomenon, venous congestion of the extremity, or high-cardiac-output state.

Major vascular complications after TRA are uncommon, and their consequences are generally benign when recognised early and managed appropriately.

NURSING CONSIDERATIONS

Procedural Care and Patient Comfort

Identification bands and peripheral intravenous lines should not be placed near the potential puncture site;

Interventions to reduce RA spasm are important to procedural success and include maintenance of a comfortable temperature and quiet environment during the procedure.

Assessing the level of anxiety is crucial in this situation. A decision can be made prior to the procedure by the scrub sister when doing the 2minute pause. The anaesthetist can make the decision if they are present. Otherwise, if the patient is moderately nervous diazepam 2.5mg-10mgs can be administer otherwise dormicum and fentanyl, if the patient is very anxious.

Post procedural care

Acute symptomatic RAO is extremely rare, but the presence of finger pain, weakness, discolouration, reduced temperature, or sensory deficit should prompt immediate evaluation. First, check that the pressure bandage (Quikclot or TR band) has not been applied too tight.

Use the O2 satuation monitor on the thumb, to check perfusion to the hand.

There is Consensus that shorter compression times result in lower rates of RAO. It is recommended that RA compression time for 60 minutes post diagnostic angiogram where the patient was administered 3000-5000units heparin and for 120 to 180 minutes after PCI (5000-1000u heparin) was administered. Slightly longer compression times may be considered for patients with uninterrupted oral or intravenous coagulation. Assessment for forearm or wrist haematoma is important. Compartment syndrome can occur if the haematoma is not promptly recognised and identified or appropriately controlled. In rare cases venous pooling may also cause pain and contribute to compartment syndrome. Be aware if the IV infusion line is in the same hand!

Early ambulation depends on effects of procedural sedation.

Careful observations should take place until the pressure bandage TR band has been removed.

Arterial monitoring is important to ensure non-occlusive haemostasis.

Avoid BP monitoring and blood sampling from procedural arm.

Specific Recommendations: Proper inservice training by the cath lab staff and device manufacturer is crucial.

CONCLUSION:

The mortality benefit is observed in high-risk ACS (eg, STEMI, cardiogenic shock) and in patients with high predicted bleeding risk.

Compared to TFA, TRA is associated with improved quality of life, reduced healthcare resource use, and reduced healthcare costs.

Most of all, patients prefer the radial approach as they can mobilise earlier and are not so restricted. Also, they can be discharged earlier.

TR Band

3.3 Percutaneous Coronary Intervention (PCI)

Percutaneous Coronary Intervention (PCI) has developed during the past 30 years to become the preferred method of revascularisation for ischaemic heart disease. CABG (coronary artery bypass grafts) is still indicated for left main artery disease and complex multi-vessel coronary artery disease (CAD).

The term percutaneous coronary intervention encompasses the broad array of the balloons, stents and adjunct devices required to perform a safe and effective procedure.

For the treatment of coronary artery disease and acute coronary syndromes, balloons assisted by stents are the main tools used to dilate the coronary stenosis.

The construction material of the balloon determines its compliance and burst pressure. The balloon polymer has been changed many times since the original design and is typically now a nylon derivative.

Modern standard or workhorse balloons are semi-compliant. Stents are minimally shorter than their corresponding delivery balloon and are deployed at the nominal or higher pressures.

A non-compliant balloon is useful in post-dilatation of a stent, when maximum stent size can be achieved without overstretching the vessel at the stent edges. A non-compliant balloon concentrates its dilating force more directly at the diseased segment of the vessel without stretching the adjacent normal segment (dog bone effect). With high inflation pressure, this balloon may break a calcified plaque and shift the atherosclerotic burden equally along the longitudinal axis, and reconstruct a bigger and more stable lumen (Butler: 2007).

With the treatment of ever increasingly complicated atherosclerotic disease, predilatation prior to stent deployment and to some degree post-dilatation are now their main indications. Freed (1992) differentiates between two main types of balloon catheter systems:

- Over the wire system: this system can accommodate longer balloons, loaded onto the guide wire from either the front or back due to the hollow core design along their length. Because of the guide wire support, these balloons are more flexible and trackable.
- Monorail balloons, also known as Rapid Exchange (RX); the advent of the monorail catheter in 1985, simplified PCI and contributed to the increase of PCI as a technique. It is designed to be easily handled by one person. This balloon loads only from the distal end, with the guide wire usually exiting approximately 30 cm from the tip. This enables the operator to control both wire and balloon while crossing through and away from the coronary artery. The Monorail principle is now used for other techniques including intravascular ultrasound and also fractional flow reserve (FFR) and

instant wave free ratio (IFR).

- Cutting balloon catheters: employ slow, low pressures to release the wire cutters/blades which slice through heavily calcified or scarred lesions. These techniques lower the risk of arterial trauma.
- Drug eluting balloon: has a cytotoxic/antiproliferative coating. It is beneficial for lesions that have in-stent restenosis and bifurcation lesions in small vessels. It is also indicated for acute or impending vascular occlusion.
- Rotablator: mechanical debulking of atherosclerotic plaques (calcified) prior to stent placement. It is also indicated for ostial lsions and diffusely diseased vessels.

INDICATIONS FOR THE PCI PROCEDURE

- Acute MI
- Unstable angina with single or double vessel disease
- Acute coronary syndrome (ACS)
- Non-surgical candidates with multi-vessel disease

In patients with angina pectoris:

- Severe, stable angina resistant to medication
- Occlusion of LAD or when triple-vessel disease is suspected on the basis of an exercise tolerance test
- Ischaemic ST-segment changes (> 2mm) with low heart rate
- Inadequate rise in blood pressure during exercise tolerance test
- Angina after acute MI
- Pain at rest or when walking while the patient is still hospitalised
- Angina and severe heart failure (myocardial stunning)
- ST-segment depression on exercise ECG

In patients without angina:

- Survivors of ventricular fibrillation without an MI
- When the exercise ECG is pathological
- In acute pulmonary oedema without a diagnosed cause
- After T-wave infarction (non ST segment elevation myocardial infarction (NSTEMI))
- Management of acute imminent myocardial damage
- When thrombolysis is contraindicated because of risk of bleeding or because it is not effective

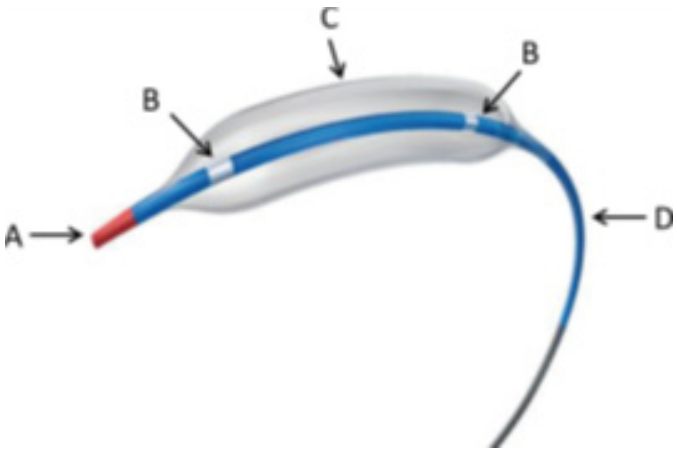
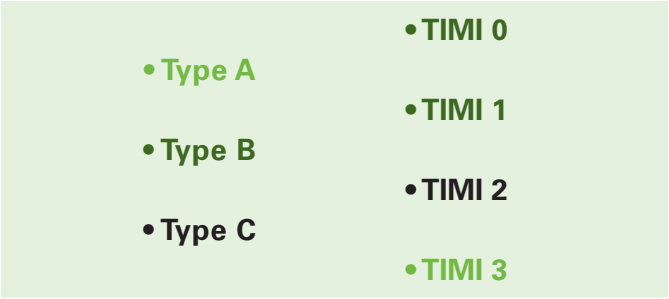


Figure 9.2: The PTCA balloon

a. *Radiopaque tip of the balloon catheter. This tip is also used for guide wire placement.*
b. *Radiopaque markers of the balloon. Balloons may also have a single marker in the middle of the balloon especially smaller balloons.*
c. *The inflated balloon.*
d. *The shaft of the balloon catheter. The exiting lumen of the guide wire is also located on the shaft.*

Lesion Typology and TIMI Classification



The American College of Cardiology (2012) differentiates between the following lesions:

Type A Lesions
(High success, low risk)

- Discreet (< 10 mm length)
- Concentric
- Readily accessible
- Non-angulated segment, <45°
- Smooth contour
- Little or no calcification
- No ostial location
- No major branch involvement
- Absence of thrombus

Type B Lesions
(Moderate success, moderate risk)

- Tubular (10 – 20 mm length)
- Eccentric
- Moderate tortuosity of proximal segment
- Moderate angulated segment: > 45°, < 90°
- Irregular contour
- Moderate to heavy calcification
- Total occlusions < 3 months old
- Ostial involvement
- Bifurcation lesions requiring double guide wires
- Some thrombus present

Type C Lesions
(Low success, high risk)

- Diffuse (> 2 cm length)
- Excessive tortuosity of proximal segment
- Extremely angulated segments > 90°
- Total occlusion > 3 months old
- Inability to protect major side branches
- Degenerated vein grafts with friable lesions

PERFORMING A PERCUTANEOUS CORONARY INTERVENTION

- When preparing for angioplasty, the following stock is needed:
  - Haemostatic valve
  - Needle introducer for guide-wire
  - Indeflator
  - 15 – 20 ml contrast medium that is mixed with Heparin/Saline
  - Guiding catheter
  - Angioplasty balloon
  - Guide-wire
  - Wet Heparin/Saline swabs
  - Torque device
- The haemostatic valve is connected to the hub of the guiding catheter and it must be flushed
- Always confirm correct size of the balloon with the cardiologist and floor nurse
- Remove the balloon from packaging and keep the inflation pressure guide
- Flush the balloon tip using supplied needle-connector. The balloon can also be wet with heparin/saline solution
- Apply a 3-way tap (high pressure tap) to the hub of the balloon and vent the balloon by applying suction and withdrawing the air from the balloon chamber twice using a 10ml syringe with a small amount of saline in it. Venting ensures a small deflated profile

- Do not remove the 3-way tap from the balloon.
- Turn it OFF towards the balloon, just in case it is needed again, it is ready to be inserted
- The 0.14mm guide-wire is threaded through the O-ring using the needle introducer
- The needle introducer is removed before balloon is introduced onto the guide wire
- The balloon will be threaded over the guide-wire; and when the guide-wire appears from the side, SECURE IT with your hand, on the bed or to the leg of the patient
- Let go of the wire once the cardiologist has control of it
- Using fluoroscopy, the balloon is now positioned through the intimal lesion
- Connect the balloon to the indeflator device
- The cardiologist will ask the scrub nurse to inflate the balloon to nominal pressure or higher and maintain that pressure for a limited time period — 10-60 secs depending on the lesion
- Check that the balloon is totally deflated before allowing it to be removed from the vessel
- DO NOT PULL ON THE SYSTEM AT ANY TIME DURING THE PROCEDURE!!!!
- When a satisfactory result has been achieved, the cardiologist removes the balloon, but leaves the guide wire in place to safeguard access
- A contrast injection is done, and flow and complications are assessed
- Intra-coronary injection of nitrates (100 - 200 mcg) may be injected depending on patients blood pressure (BP).

REMEMBER: Anticoagulation must always be given prior to procedure and nitrates (TNT) must be prepared for the use in vasospastic events.

COMPLICATIONS FOLLOWING PCI

1. Coronary dissection
2. Abrupt vessel closure
3. MI
4. Occlusion of side branches ("snow-plow" effect)
5. No re-flow phenomenon
6. Dysrhythmias
7. Restenosis
8. Coronary spasm

Possible balloon related complications

- Plaque rupture/dissection – over-expansion of the balloon in relation to the size of the vessel may lead to balloon rupture and damage to the vessel wall/plaque causing cardiac tamponade. This will lead to hypotension, chest pain and shock. It may also occur when the vessel is calcified.
- Balloon-induced dissection can also occur when the guiding catheter is wedged too deeply in the ostium of the artery
- Stent loss – when there is calcium present in the artery or the lesion is tightly stenosed, the stent may become dislodged from the balloon
- Vessel occlusion/thrombus usually occurs in the presence of AMI or ACS. There is often a large thrombus load present in the artery that may or may not be seen by the cardiologist. Severe coronary artery spasm and dissection of the artery following balloon inflation, may also cause occlusion
- Balloon rupture - may occur with normal pressures, when calcium is present or when the balloon is inflated beyond the rated burst pressure (RBP). There will be a pressure drop on the indeflator face dial, and blood is noticed in the hub of the balloon
- Balloon trapping - may occur in calcified lesions

or even stent struts resulting in membrane fragments shearing off
- Coronary embolisation - distal embolisation in degenerated vein grafts. A distal protection device is recommended
- Micro-embolism in native vessels is often not recognised
- System embolisation of material within coronary arteries, especially when they are filled with loose arterosclerotic or thrombotic material

MULTI VESSEL PCI

Initially, PCI was used for simple or low-risk lesions only. As technology improved and especially when stents became available, increasingly complex lesions were treated with PCI.

Traditionally, patients with multi-vessel coronary artery disease unresponsive to medical treatment, have required surgical revascularisation to improve symptoms and functional capacity. With advances in angioplasty devices and improved operator skills, patients with multi-vessel disease are increasingly treated with PCI.

Small randomised and retrospective studies regarding multivessel disease showed the following:

- High procedural success rates can be achieved
- Early and late complication rates are low, although higher than encountered in single vessel PCI
- Restenosis, clinical recurrence and repeat PCI are common
- Symptomatic improvement is excellent
- CABG can be avoided in some patients

Controversy arose between cardiac surgeons and invasive cardiologists as to what the best treatment for multivessel and left main stem disease is. Two landmark studies were recently published which have identified which of these patients do better with either strategy. (See abstracts of SYNTAX Trial and FREEDOM Trial on pages 94-95)

It is important to understand the Syntax scoring system to make sense of the SYNTAX trial:

The SYNTAX score is an angiographic grading tool to determine the complexity of coronary artery disease. It was developed by taking various previous scoring systems into consideration which included the AHA scoring system, the Leaman score, the ACC/ AHA lesion classification system, the total occlusion classification system, the Duke and International Classification for Patient Safety (ICPS) classification for bifurcation lesions and a consensus opinion from among the world experts. Each individual lesion in the coronary tree with > 50% diameter narrowing in vessels > 1.5% mm diameter is assessed and points are assigned according to different lesion characteristics, including lesion length, calcification, tortuosity, bifurcation involvement, total occlusion duration, aorto-ostial lesions, etc. The coronary tree is divided in 16 segments according to the AHA classification. Each segment is given a score of 1 or 2 based on the presence of disease and this score is then weighted based on a chart with values ranging from 3.5 for proximal LAD to 5.0 for left main and 0.5 for smaller vessels. The score for all the lesions is added to get a total SYNTAX score. The score is divided in tertiles, with scores of 0-22 the lowest risk lesions, 23-32 intermediate risk and

values above 33 the highest risk. For more detail go to the online SYNTAX risk calculator: www.syntaxscore.com

ABSTRACT

SYNTAX Trial

Lancet. 2013 Feb 23;381(9867):629-38. doi: 10.1016/S0140-6736(13)60141-5.

Coronary artery bypass graft surgery versus percutaneous coronary intervention in patients with three-vessel disease and left main coronary disease: 5-year follow-up of the randomised, clinical SYNTAX trial.

Mohr FW, Morice MC, Kappetein AP, Feldman TE, Ståhle E, Colombo A, Mack MJ, Holmes DR Jr, Morel MA, Van Dyck N, Houle VM, Dawkins KD, Serruys PW.

Background:

We report the 5-year results of the SYNTAX trial, which compared coronary artery bypass graft surgery (CABG) with percutaneous coronary intervention (PCI) for the treatment of patients with left main coronary disease or three-vessel disease, to confirm findings at 1 and 3 years.

Methods:

The randomised, clinical SYNTAX trial with nested registries took place in 85 centres in the USA and Europe. A cardiac surgeon and interventional cardiologist at each centre assessed consecutive patients with de-novo three-vessel disease or left main coronary disease to determine suitability for study treatments. Eligible patients suitable for either treatment were randomly assigned (1:1) by an interactive voice response system to either PCI

with a first-generation paclitaxel-eluting stent or to CABG. Patients suitable for only one treatment option were entered into either the PCI-only or CABG-only registries. We analysed a composite rate of major adverse cardiac and cerebrovascular events (MACCE) at 5-year follow-up by Kaplan-Meier analysis on an intention-to-treat basis. This study is registered with ClinicalTrials.gov, number NCT00114972.

Findings:

1800 patients were randomly assigned to CABG (n=897) or PCI (n=903). More patients who were assigned to CABG withdrew consent than did those assigned to PCI (50 vs 11). After 5 years' follow-up, Kaplan-Meier estimates of MACCE were 26·9% in the CABG group and 37·3% in the PCI group (p<0·0001). Estimates of myocardial infarction (3·8% in the CABG group vs 9·7% in the PCI group; p<0·0001) and repeat revascularisation (13·7%vs 25·9%; p<0·0001) were significantly increased with PCI versus CABG. All- cause death (11·4% in the CABG group vs 13·9% in the PCI group; p=0·10) and stroke (3·7%vs 2·4%; p=0·09) were not significantly different between groups.

28·6% of patients in the CABG group with low SYNTAX scores had MACCE versus 32·1% of patients in the PCI group (p=0·43) and 31·0% in the CABG group with left main coronary disease had MACCE versus 36·9% in

the PCI group (p=0·12); however, in patients with intermediate or high SYNTAX scores, MACCE was significantly increased with PCI (intermediate score, 25·8% of the CABG group vs 36·0% of the PCI group; p=0·008; high score, 26·8%vs 44·0%; p<0·0001).

Interpretation:
CABG should remain the standard of care for patients with complex lesions (high or intermediate SYNTAX scores). For patients with less complex disease (low SYNTAX scores) or left main coronary disease (low or intermediate SYNTAX scores), PCI is an acceptable alternative. All patients with complex multivessel coronary artery disease should be reviewed and discussed by both a cardiac surgeon and interventional cardiologist to reach consensus on optimum treatment.

(Ref:http://www.ncbi.nlm.nih.gov pubmed/23439102)

Diabetic patients have a higher incidence of complications in most lesion subsets and previous data to guide their treatment was obtained from the diabetic subgroups of larger studies. A recently published landmark trial (FREEDOM Trial) specifically deals with PCI vs coronary bypass grafting (GABG) in this important group of patients.

ABSTRACT

Strategies for Multivessel Revascularisation in Patients with Diabetes

Michael E. Farkouh, M.D., Michael Domanski, M.D., Lynn A. Sleeper, Sc.D., Flora S. Siami, M.P.H., George Dangas, M.D., Ph.D., Michael Mack, M.D., May Yang, M.P.H., David J. Cohen, M.D., Yves Rosenberg, M.D., M.P.H., Scott D. Solomon, M.D., Akshay S. Desai, M.D., M.P.H., Bernard J. Gersh, M.B., Ch.B., D.Phil., Elizabeth A. Magnuson, Sc.D., Alexandra Lansky, M.D., Robin Boineau, M.D., Jesse Weinberger, M.D., Krishnan Ramanathan, M.B., Ch.B., J. Eduardo Sousa, M.D., Ph.D., Jamie Rankin, M.D., Balram Bhargava, M.D., John Buse, M.D., Whady Hueb, M.D., Ph.D., Craig R. Smith, M.D., Victoria Muratov, M.D., M.P.H., Sameer Bansilal, M.D., Spencer King, III, M.D., Michel Bertrand, M.D., and Valentin Fuster, M.D., Ph.D. for the FREEDOM Trial Investigators.

In some randomized trials comparing revascularisation strategies for patients with diabetes, coronary-artery bypass grafting (CABG) has had a better outcome than percutaneous coronary intervention (PCI). We sought to discover whether aggressive medical therapy and the use of drug-eluting stents could alter the revascularisation approach for patients with diabetes and multivessel coronary artery disease.
In this randomized trial, we assigned patients with diabetes and multivessel coronary artery disease to undergo either PCI with drug-eluting stents or CABG. The patients were followed for a minimum of 2 years (median among survivors, 3.8 years). All patients were prescribed currently recommended medical therapies for the control of low-density lipoprotein cholesterol, systolic blood pressure, and glycated hemoglobin. The primary outcome measure was a composite of death from any cause, nonfatal myocardial

infarction, or nonfatal stroke.

From 2005 through 2010, we enrolled 1900 patients at 140 international centers. The patients' mean age was 63.1± 9.1 years, 29% were women, and 83% had three-vessel disease. The primary outcome occurred more frequently in the PCI group (P=0.005), with 5-year rates of 26.6% in the PCI group and 18.7% in the CABG group. The benefit of CABG was driven by differences in rates of both myocardial infarction (P<0.001) and death from any cause (P=0.049). Stroke was more frequent in the CABG group, with 5-year rates of 2.4% in the PCI group and 5.2% in the CABG group (P=0.03).

For patients with diabetes and advanced coronary artery disease, CABG was superior to PCI in that it significantly reduced rates of death and myocardial infarction, with a higher rate of stroke. (Funded by the National Heart, Lung, and Blood Institute and others; FREEDOM ClinicalTrials.gov number, NCT00086450.)

(Ref: http://www.nejm.org/doi/full/10.1056/ NEJMoa1211585?viewType=Print&view¬Class=Print)

The strategy for multi-vessel PCI

Butler et al (2007), Nguyen (2008) and Kern (2011) propose the following strategy when attempting multi-vessel PCI:

1. Total occlusions which supply large jeopardised areas or furnish collaterals, are dilated first. If the vessel has closed acutely then it is best to stage the procedures – do the culprit lesion first and bring the patient back at a later stage to do further lesions
2. If the culprit vessel is small or cannot be identified, dilate the most important stenosis (i.e. the vessel with the largest jeopardised area)
3. If two stenoses are present in vessels of equal calibre and distribution, the better collateralised vessel is done first
4. When both proximal and distal stenoses are present, dilate the distal lesion first, allowing the balloon to retain its lowest profile as it is advanced across the more distal stenosis. If the balloon does not cross the proximal stenosis easily, or impedes flow, this site is dilated first.

RESTENOSIS

After successful balloon angioplasty, the body attempts to repair the damage caused by balloon injury. Within minutes, platelets and fibrin are deposited at the injury site. Inflammatory cells start to infiltrate the injury site and vascular smooth muscle cells starts to migrate from the tunica media to the intima (Di Mario: 2011).

Di Mario (2011) asserts that these smooth muscle cells and fibroblasts proliferate and hypertrophy in the process, secreting excessive amounts of cellular matrix. Along with this proliferative neointimal response, there is elastic recoil and fibrotic contraction. There is loss in lumen diameter, and the patient's symptoms may reappear. Restenosis rates are lower when stents are deployed as compared to balloon alone. In complicated cases, restenosis rates after 6 months range from 20 - 50% for balloons balloon angioplasty.

DEALING WITH OSTIAL LESIONS

The presence of an ostial lesion poses a special

man-agement problem. Although these lesions frequently appear well-suited for balloon angioplasty (focal and concentric), this method of revascularisation has resulted in increased procedural failure, complications and restenosis rates when compared to non-ostial lesions.

Ostial lesions tend to have higher calcium and fibrous tissue content and increased elastic recoil tendency. There is also an increase in intimal hyperplasia after stenting of ostial lesions. Nguyen (2008) advocates the use of a drug eluting stent when stenting an ostial lesion to combat hyperplasia. Despite these disadvantages, precise stent placement and deployment must be achieved to avoid geographical miss or compromise the branches involved.
Combating catheter-induced ostial vasospasm will be very challenging to the cardiologist. The location of these lesions poses inherent challenges to the cardiologist due to:

- Limited angiographic views
- Highly variable ostial anatomy
- Unstable guide catheter support
- Accentuated cardiac motion
- Significant myocardium at jeopardy

Other concerns when embarking on angioplasty or stenting of ostial lesions are:

- The balloon or stent can impinge on the origin of the non-dilated artery and obstruct flow
- If there is acute vessel occlusion, there could be significant jeopardy to cardiac function or patient survival
- There are significant vessel size differences of the left main artery compared to the LAD or circumflex artery
- Dissection at the proximal LAD and CXA could extend in a retrograde fashion into the left main segment properly positioned

CLASSIFICATION OF OSTIAL LESIONS

1. Aorto-ostial: a lesion that involves the junction between the aorta and the orifice of the right coronary artery, left main or saphenous vein graft.
2. Branch-ostial: a lesion that involves the junction between a large epicardial vessel and the orifice of a major branch
3. Near-ostial: a lesion located within 3 mm but not necessarily involving the orifice of the involved artery

CONSIDERATIONS FOR THE REGISTERED NURSE WHEN ASSISTING THE CARDIOLOGIST

1. Ensure that a full surgical team is available for back-up
2. All emergency equipment must be checked and available, and all resuscitation drugs must be ready. It is advisable to have a covered stent as a bail-out strategy in the catheterisation laboratory
3. Drugs to treat no-reflow and vasospasm must be ready on the work station
4. Dampening of arterial pressure will ensue upon vessel engagement. A smaller size catheter may be used. Side hole catheters can also be utilised
5. Guiding catheter engagement with the ostium should be avoided as much as possible during the procedure to decrease catheter induced ostial trauma and vessel spasm
6. Judkins guide catheters and mostly short tip catheters provide the best support. Multipurpose catheters have also proven to be beneficial

7. It is usually possible to advance and centre the balloon with the guiding catheter positioned just outside the ostium as long as coaxial alignment is maintained between the catheter tip and the major axis of the proximal vessel segment
8. If balloon inflation results in hypotension, consider brief balloon inflations
9. A non-compliant balloon delivers the best result in pre-dilation of ostial lesions
10. The balloon should never be fully inflated while partially situated within the guiding catheter (will result in balloon rupture). It is essential to gently retract the guiding catheter. As the majority of collaterals originate from the contra-lateral artery, this requires a double injection technique
11. When dilating branch-ostial lesions (especially ostial LAD or circumflex artery), the balloon should be positioned to avoid obstructing blood flow down the uninvolved branch of the bifurcation

In the case of ostial lesion stenting:

12. The use of short stents should be avoided to provide adequate anchoring of the stent and ensure full coverage of the lesion
13. Stents are deployed using high inflation pressures (> 12 atm) to ensure optimal stent apposition
14. A second higher pressure balloon inflation may be done with the stent balloon slightly retracted allowing full stent apposition at the ostium

DEALING WITH A CHRONIC TOTAL OCCLUSION LESION (CTO)

Mario et al (2011) defined a chronic total occlusion as an occlusion of at least three months, and with absolutely no flow through the lesion itself (TIMI 0 flow). Occlusions within 1 – 3 months' duration can therefore be addressed as recent occlusions, and within a period of four weeks or less following an acute myocardial infarction, as sub-acute occlusions.

Another important characteristic of a CTO is the length of the occluded segment. This can be assessed through simultaneous visualisation using 2 catheters. Stent restenosis at the proximal end could result in restenosis of the left main artery. There is an increased incidence of antegrade and retrograde embolisation into the other artery

For the interventional strategy of entering, crossing and exiting the occluded segment, it is important to keep the basic patho-anatomical features of a CTO in mind:

- The proximal cap of the occlusion is often fibrotic or calcified and may provide considerable resistance to guide wire advancement
- The occlusion is associated with loose fibrous tissue and organised thrombus. It may include islets of calcification, which provide an obstacle to the advancement of the wire through this part of the occlusion until the distal cap is encountered

INDICATIONS FOR REVASCULARISATION OF A TOTAL OCCLUSION LESION

Di Mario (2011) stipulates the following indications for revascularisation of a chronic total occlusion (CTO):

1. Medically refractory angina which significantly interferes with the patient's life style

2. A large area of silent ischaemia
3. The occlusion portrays a favourable appearance

POSSIBLE BENEFITS OF REVASCULARISATION OF THE TOTAL OCCLUSION LESION

Di Mario (2011) indicates the following benefits associated with revascularisation of a CTO:

1. Relief of exertional angina
2. Improvement in left ventricular function
3. It serves as a collateral source to other vessels
4. May improve prognosis with myocardial infarction in a second vascular territory
5. May favourably affect ventricular remodelling

PROCEDURAL SUCCESS FACTORS

Nguyen et al (2008) reveals that the success of revascularisation of a total occlusion depends on the following factors:

1. Functional total occlusion (fainting, delayed opacification of vessel segment beyond occlusion) are present
2. Age of lesion < 12 weeks
3. Length of lesion < 15 mm
4. Presence of a tapered stump
5. Absence of a side branch at point of occlusion
6. Absence of intra-coronary bridging collaterals

COMPLICATIONS ASSOCIATED WITH REVASCULARISATION OF A TOTAL OCCLUSION

1. Acute closure of the vessel
2. MI
3. Death
4. Emergency bypass surgery due to vessel dissection
5. Thrombosis in proximal cardiac vessels
6. Embolisation of inter-coronary collateral vessels
7. Coronary vessel perforation
8. Guide wire entrapment and fracture
9. Dysrhythmias
10. Excessive contrast load
11. Excessive fluoroscopic time
12. Restenosis

GUIDELINES FOR THE REGISTERED NURSE WHEN ASSISTING THE CARDIOLOGIST IN THE CTO PROCEDURE

1. A guiding catheter providing co-axial back-up is essential
2. Floppy, intermediate and standard wires may not be adequate in penetrating the lesion
3. Additional back-up support can be obtained by trailing the balloon catheter 1 – 2 cm behind the tip of the guide wire into the occlusion
4. During crossing attempts, the guide wire should be directed along the major axis of the vessel
5. Between crossing attempts, the guide wire is rotated with 10 – 20 degrees in the hope of finding a soft, potential channel to penetrate
6. Small contrast injections are performed to ensure intraluminal guide wire position prior to balloon inflation
7. If wall staining is noticed, subintimal wire passage has occurred and requires guide wire withdrawal and repositioning. Free rotation and easy advancement/retraction of the guide wire beyond the site of occlusion is evidence of intra-luminal positioning.
8. Balloon inflation of a subintimal tract must be avoided due to the increased risk of vessel perforation
9. A small high-pressure balloon is initially chosen and then up-sized

WIRE HANDLING

Kern (20110) explains that there are 3 technical approaches to handle the interventional guide

wire in approaching the CTO:

1. **Controlled drilling technique**
   This is ideal for occlusions with a distinct entry point. Typical wires for this approach are moderately stiff wires with a high torque-control. The tip diameter of these wires is like normal work horse wires with a 0.014 inch, but the enforcement of the tip is incremental. The wire handling for drilling consists of a very slow advancement of the wire into the occlusion with a turning movement on the torque handle less than 90 degrees in each direction in alternative ways.
2. **The penetrating technique**
   This approach is ideal for occlusions without any discernible entry point, typically at the site of side branches. The penetration requires smaller tip wires with a 0.010 inch tip diameter or 0.009 inch tip diameter. These wires provide increasing tip stiffness, and with the latter, additional hydrophilic coating except for the wire tip, which reduces friction of the wire and enhances the penetrating force.
3. **The sliding technique**
   This technique rests on the low friction advancement of hydrophilic coated wires and is ideal for occlusions with a suspected residual lumen.

No single technique serves all lesions, and all approaches should be utilised and used in combination.

CORONARY ARTERY STENTS

Coronary stents are currently used in 90% of PCI procedures. The most important benefit of stents is the effective treatment of abrupt closure following balloon angioplasty. Abrupt balloon closure was associated with an increased risk of death (5%), MI (40%) and the need for emergency coronary artery bypass surgery (40%). With the advent of stents there was a significant decrease in these adverse events.

The term "stent" was coined in 1916 by Jan F. Esser, a Dutch plastic surgeon referring to a dental impression compound already invented by the English dentist, Charles Thomas Stent. The first vascular stent was developed and implanted in 1968 by Charles Dotter in a canine popliteal artery.

The first coronary stent was implanted in 1986 in Toulouse, France. It was a self-expanding Wall stent. Intra-coronary stent placement was not a routine procedure and was used as "bail-out" device for treating coronary dissection. The restenosis and occlusion rates post coronary stenting was high. Following the Wall stent, the Palmaz-Shatz stent (balloon expandable) was introduced in 1989, and paved the way for the development of and array of intra-coronary stents (Baim & Grossman:2000).

A stent can be defined as a small mesh cylinder. It is a metallic scaffold that is deployed within the diseased segment of a coronary artery to establish and then maintain a widely patent lumen. Stents are made from stainless steel, tantalum, nitinol, cobalt chromium alloys and platinum.

Drug Eluting Stent

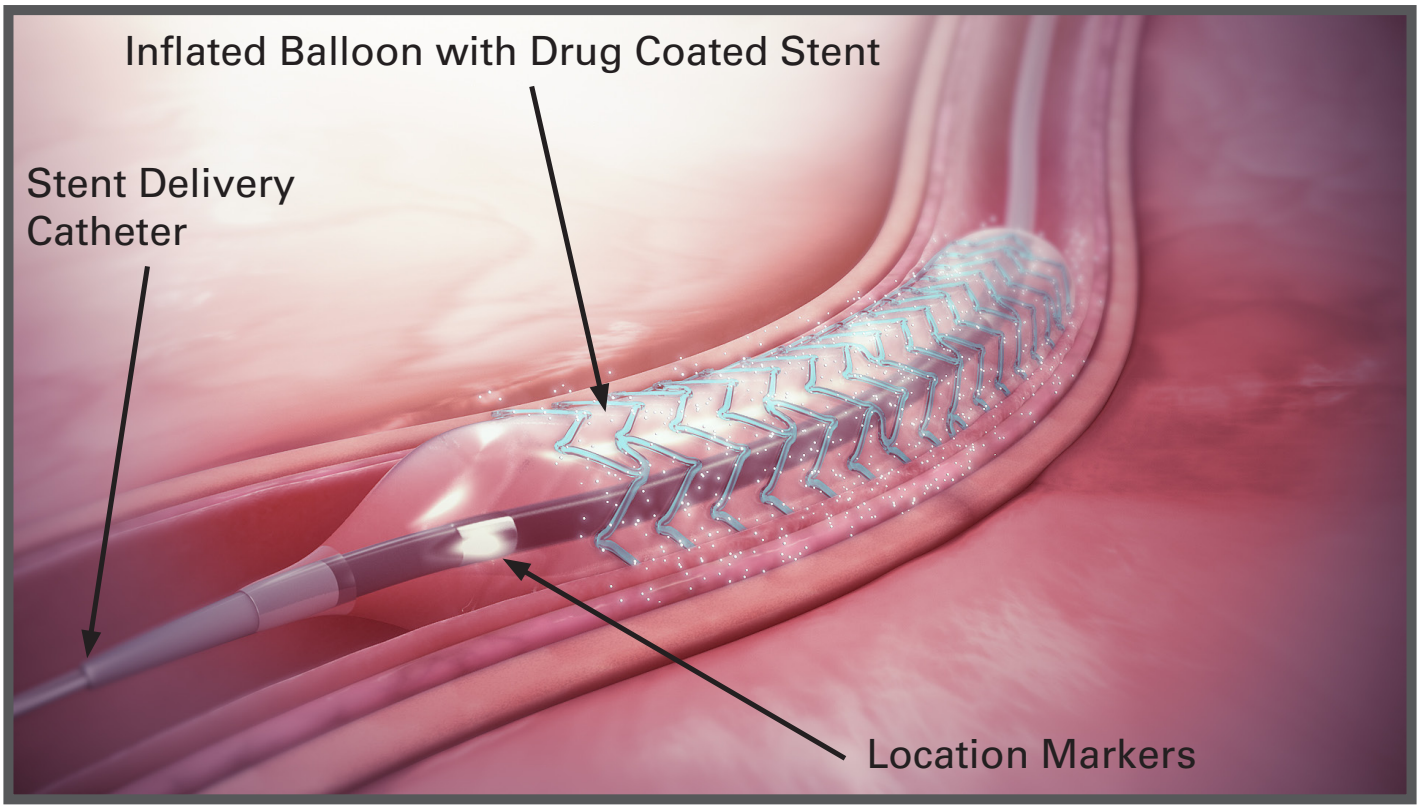


Fig 9.3: Drug Eluting Stent

By Manu5 - http://www.scientificanimations.com/wiki-images/, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=70777398

Stents differ in their composition (construction material), architecture (slotted tube or coiled wire) and mode of implantation (balloon-expandable or self-expanding). Majority of coronary stents are now balloon expandable. Diameters vary from 2mm to 5mm, and lengths from 6mm to 60mm.

Balloon expandable stents are delivered into the coronary artery in a collapsed state, mounted onto a delivery balloon. Once placed in the desired location, the delivery balloon is inflated and the stent expands and imbeds itself into the artery wall. Balloon expandable stents are the slotted tube, wire coils and modular design stents.

The latest generation of stents have been developed to be more flexible in a collapsed state. These stents are laser cut in unique multicellular patterns (from metallic tube) which increased the flexibility throughout the stent length without compromising radial strength or elastic recoil (Di Mario: 2011)

The quality of coronary stents has also improved markedly over time. It has quickly become the standard of care, and they are being implanted in more than 80% of interventional procedures.

INDICATIONS

As operator experience increases and stent materials and design improve, the indications for intracoronary stenting will continue to widen.

- Treatment of abrupt coronary occlusion and prevention of threatened coronary occlusion after PCI
- Primary treatment to reduce restenosis in focal lesions
- Saphenous vein graft disease; internal mammary & radial artery grafts disease
- Suboptimal results after angioplasty
- Chronic total occlusions
- Restenotic lesions after angioplasty
- Restenotic lesions after prior stent placement
- PCI for acute infarction

CONTRAINDICATIONS

It is the operator's decision whether to stent or not. Not every patient will going to benefit from stenting and in some cases, the operators may decide to do nothing, or may just do `plain old balloon angioplasty '(POBA).

Relative contraindications for stent placement are:

- Stenting will occlude a major side-branch
- Patient cannot take clopidogrel
- Large thrombus burden, with patent vessel
- Unable to pass a quid ewire down the vessel due to organised thrombus

The key components for coronary artery stent platforms are:

- Good deliverability with a low and flexible profile
- High radial strength to prevent elastic recoil and limit foreshortening
- Sufficient plaque coverage to avoid tissue prolapsed

COMPLICATIONS OF INTRA-CORONARY STENTS

- **ACUTE AND SUB-ACUTE STENT THROMBOSIS**

  Surface charge, surface texture and surface energy all contribute to the thrombogenetic potential of metallic endovascular devices or prostheses. Although stents attract platelets,

they undergo passivation as proteinaceous material is deposited on the stent surface and thus changing the resting potential of the alloy. This can be treated by using Aggrastat during the procedure, or preloading the patient with Clopidogrel. Also, ensuring that the patient has had ecotrin (aspirin) prior to coming to the cath lab.

A higher incidence of stent thrombosis is found in patients with a hypercoagulable state, long lesions, bifurcating lesions, small vessels, ostial lesions and slow flow through vessels.

- **SIDE-BRANCH ARTERY OCCLUSION**:
(Snow plough effect – debris is pushed by balloon inflation into the near-by vessel).

It can be avoided by placing a wire down the side-branch which is at risk.

- **INCOMPLETE STENT EXPANSION AND STRUT APPOSITION**: this is due to the balloon rupturing or lesion that has not been cracked completely. A non-compliant balloon can overcome this problem, and the use of 'Clear stent' or similar modality twhich the radiographer can provide. We are fortunate now that although many stents lack radiopacity we can clearly visualize them, using other methods. The non-compliant balloon used post stent deployment to optimise stent apposition should be shorter than the stent to prevent further complications.

- **VESSEL DISSECTION/EDGE DISSECTION:** This can occur post stent deployment when the stent has been taken to a high pressure! The alarm bell is usually the patient complaining of severe chest pain that is not resolving. There may not be significant ECG changes. It can also be caused by a wire migrating out of the vessel into the muscle. Often the radiographer will identify the culprit angiographically. OCT may be used to visualise dissection. IVUS is not advisable if dissection is suspected. The treatment is usually to deploy a second stent distal or proximal to the previous one and make it long enough so that it can cover the dissected area adequately.

- **VESSEL PERFORATION:** this is caused by the stent being too large for the artery or being deployed at an excessive pressure. A covered stent or 'rescue stent' can be used to occlude the area of perforation.(It is important to keep a suitable range in the cath lab).

- **CORONARY ARTERY SPASM:** post stent deployment, it is common for the artery to respond to the high pressure by going into spasm. The patient will complain of severe chest pain. It is important that the patient is reassured adequately by the floor nurse. Also, post stent deployment it is common for the patient to feel stretch pain for a few hours. Perfalgen may be administered slowly via the IV. This is easily overcome by injecting nitrocine 100mcgms -200mcgms intra-coronary (IC) via the guide catheter

- **DONE-BONING** – lesion area doesn't expand. A non-compliant balloon is required to expand the stent adequately. This can be seen when 'Clear Stent' modality is used by the radiographer.

- **STEP-DOWN EFFECT:** sometimes as the vessel tapers, the diameter of the coronary artery

changes. It is important to check the vessel for an edge dissection. Before taking the stent to pressures greater than the nominal pressure indicated, it is important to consider the size of the artery distal to the stent. Also, there can be a ` Step-up effect' if the wrong size stent has been deployed. Again it is important, to check for a dissection.

- **INFECTIOUS ENDO-ARTERITIS (VERY RARE: ONLY 3 CASES DOCUMENTED).**

- **IN-STENT RESTENOSIS – Bare Metal Stents (BMS)**

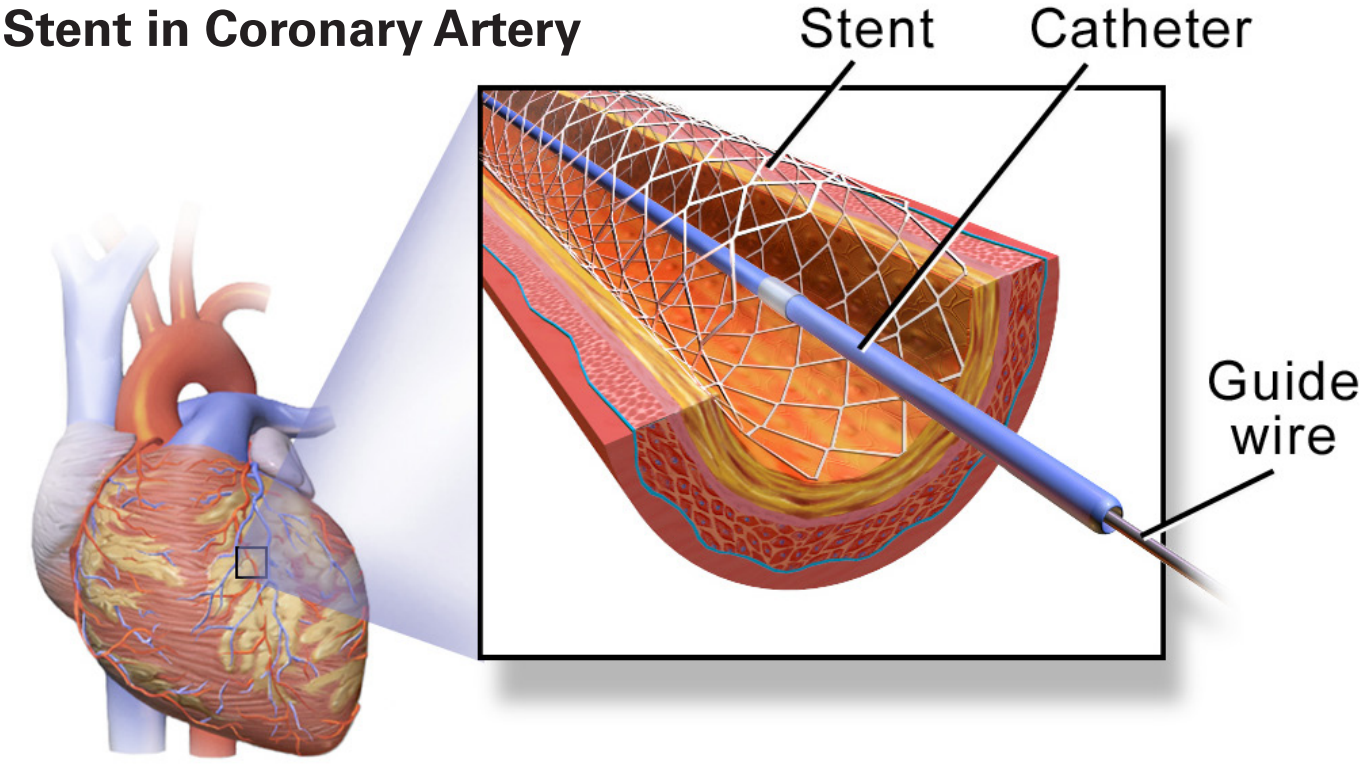
The majority of stents produce very good short-term results, but there is a phenomenon by which the vessel lumen can narrow slowly within the stent. This is caused by increased proliferative response by the vessel wall to the presence of the stent, which is a natural healing response to arterial healing. Growth within the stent is mostly due to smooth-muscle cells, which migrate from the vessel wall. This neointimal hyperplasia can occur to such a degree that the vessel may close completely, even though the original stenosis may have been moderately severe.The incidence of in-stent restenosis after BMS placement differs between studies, but it is accepted to be 20%-30%, and reaches its peak at about 6 months post stent implantation. Its incidence varies greatly between patient and lesion groups, being higher in diabetics, long lesions, and small vessels.

Restenosis can often be treated with plain old balloon angioplasty (POBA) as the material is fibrotic and can be simply molded against the wall of the artery. Other options for restenosis include rotoblator and placement of drug eluting stents. (Invasive Cardiology – third edition, Sandy Watson, Kenneth A. Gorski)

DRUG-ELUTING STENTS (DES)

Butler et al (2007) indicate that the drug-eluting stent was developed to inhibit restenosis.

The stent surface is coated with a substance that



Blausen.com staff (2014). "Medical gallery of Blausen Medical 2014". WikiJournal of Medicine 1 (2).

is released over a time period to the vessel wall. These coatings are classified as passive or active.

Passive coatings: these are substances where the vessel does not respond with neo-intimal hyperplasia.

Active coatings: release substances that disperse into the vessel wall and thus interfere with neo-intimal hyperplasia process. DES's are made up of three elements: the stent, the drug and (usually) a carrier. The carrier is often referred to as the polymer. A polymer is used to bind the drug to the stent. The polymer must bind to the stent surface without cracking on expansion and it must not trigger an inflammatory response. It releases the drug over a prescribed period of time. The drug must inhibit the restenotic process without interfering with the stent endothelialisation, and it should have a wide therapeutic window without toxicity to the tunica media and adventitia.

Attempts to eliminate the polymer as a potential source of adverse events have provoked the development of polymer-free drug carrier systems. Biodegradable polymer stents have been developed in response to the safety concerns associated with first generation DES, rendering the stent surface closer to the bare metal stent.

Polymer free drug eluting stents have also resulted in the development of polymer free drug carrier systems. They offer the advantage of avoiding long term adverse effects of a polymer, improved healing, and an improvement to the integrity of the stent's surface owing to the absence of a polymer cracking or peeling off.

Most of the currently available DES use drugs that are analogues of the sirolimus (limus family). These include: zotarolimus, everolimus, biolimus-A9, novolimus and myolimus.

Paclitaxel has been shown to inhibit vascular smooth muscle cell migration and proliferation effectively.

DES Complications

Although restenosis still occurs with DES, it is at much lower rates than with BMS's. Thrombi still form within a DES where the dissection is not completely covered, and the same may occur if the stent struts are not well opposed into the vessel wall.

When predilating, it is wise to choose a balloon shorter in length than the DES to be deployed to avoid trauma/dissection outside the stent. The DES should be long enough to cover the lesion, reaching from healthy tissue to healthy tissue. Post dilatation balloons should be semi- or noncompliant and a little shorter in length than the stent. Inflating the balloon outside the DES may result in trauma, increasing the chance of thrombosis. Using a non-compliant balloon 0.25 to 0.5 mm larger than the deployed DES may be necessary to ensure complete apposition to the vessel wall.

Restenosis is a far less serious complication than stent thrombosis, but carries approximately a 10% risk of causing a myocardial infarction.

OTHER STENT TYPES

Bioabsorbable Scaffolds:

Neointimal hyperplasia is triggered by the presence of a foreign body (the stent) in the

vessel. If the stent were to disappear over time, restenosis risk may be reduced . A few companies are developing these absorbable scaffolds that could eventually offer an alternative to metallic drug-eluting stents.

Covered Stents (Stent Grafts)

These stents have been covered with a material that becomes semi-impermeable when it is exposed to blood but porous enough to allow endothelialization.

These covered stents are used to seal pseudoaneurysms and vessel perforation. Prolonged balloon inflations or surgery are an alternative treatment in these emergency situations.

Good PCI technique and established antiplatelet regimes can reduce in-stent thrombosis. Repeat revascularization of the target vessel has been reduced to below 5%.

SUGGESTED GUIDELINES FOR THE NURSE WHEN ASSISTING IN THE PCI PROCEDURE

THE DES MUST NOT BE PLACED IN WATER PRIOR TO INSERTION

(Do not vent or suck on the Stent device, with a syringe, as it may loosen it from the balloon)

- Remove the mounted stent from the packaging, after checking the size with the cardiologist and Floor nurse
- Remove the inflation pressure chart and keep it on the procedure trolley
- Prepare the inflation device with 50:50 saline/ contrast
- The stent should be long enough to cover the proximal to distal end of the lesion
- Prolonged or forceful manipulation to cross a lesion is avoided, because the mounted stent can be stripped off the balloon
- If the stent does not track through the lesion easily then it is best to use a pre-dilating semi-compliant balloon. If calcium is present a cutting or scoring balloon may be required. A heavily calcified vessel may need to be rotoblated, in order to facilitate stent deployment
- If placement is correct, connect the indeflator to the stent delivery catheter. Ensure that all the air has been expelled from the syringe
- The Cardiologist will ask the scrub nurse to inflate the stent to the nominal pressure or higher; deflate the balloon when the time is up
- Perfect stent apposition is the golden standard
- A contrast injection should be done once the balloon is removed from the vessel to evaluate blood flow and check for dissection of the vessel
- REMEMBER: Anti-coagulation must always be given prior to the PCI. ACT must be monitored if the procedure is prolonged.
- Nitrocine (vasodilator) solution must be available on the procedure trolley for treating coronary spasm, which often occurs post stent deployment
- Verapamil and adrenaline may also be available on the procedure trolley.
- 'Clear Stent' or an alternative modality used to check that the stent has been deployed adequately
- If there is ` dog-boning' of the stent then use a non-compliant balloon to optimize the stent apposition

ADJUNCTIVE PHARMACOLOGY DURING/POST STENTING

The Cardiologist will decide when the patient is administered Clopidogrel. Some patients

have a loading dose prior to coming to the lab. Some Cardiologists may request it prior to the intervention, on the procedure table, or after the PCI has been completed.

The Cardiologist will decide the length of time that the patient will remain on DAPT. The decision will be made, depending on the patient's clinical profile and the type of stent that has been used.

The use of dual anti-platelet therapy (DAPT), together with improved stent deployment techniques has led to reductions in acute and sub-acute stent thrombosis. DAPT consists of aspirin and a thienopyridine derivative (eg. Clopidogrel, Brillinta. Prasugrel).

The Cardiologist will decide the length of time that the patient will remain on DAPT. The decision will depend on the patients clinical profile and the type of stent that has been used.

3.4 Right Heart Studies

Right heart catheterisation was first performed in 1929 by Werner Forsmann, a 25 year old medical student in Berlin. He cannulated himself with a 65 cm catheter via the ante-cubital vein, guiding it by fluoroscopy until it ended in his right atrium (Watson & Gorski: 2005)

Right heart studies are the invasive procedure whereby pressures are measured in the right atrium, right ventricle and pulmonary artery. These haemodynamic pressure measurements are used to evaluate heart function, enabling diagnosis of particular disease states.

All pressure waves of the cardiac cycle are represented by the electrical and mechanical activity of the heart. The timing of mechanical events, such as contraction and relaxation and the generation of transvalvular and ventricular pressure gradients is identified by their relationship to the ECG whose timing can be matched to the corresponding waveform.

The cardiac cycle starts with the P-wave which signals and initiates atrial contraction. Atrial systole and diastole are represented by the a-wave and x-wave respectively. The QRS-wave represents ventricular depolarisation. The LV pressure at the end of the a-wave is referred to as the left ventricular end diastolic pressure (LVEDP). The timing of this pressure point corresponds to the R-wave intersection of the LV pressure.

After the QRS-complex, the ventricles contract and the RV and LV pressures increase rapidly during the isovolumetric contraction period. When the LV pressure rises above the aortic pressure, the aortic valve opens.

Systolic ejection continues until repolarisation, which is represented by the T-wave. After the T-wave, the LV relaxation produces a fall in the LV and aortic pressure. When the LV pressure falls below the aortic pressure, the aortic valve closes. The ventricular pressure continues to fall to below the LA pressure, when the mitral valve opens and the left atrium empties into the left ventricle. When observing the atrial pressure waveform across the cardiac cycle, note that the atrial pressure during systole slowly rises with atrial filling at its maximum at the end of diastole.

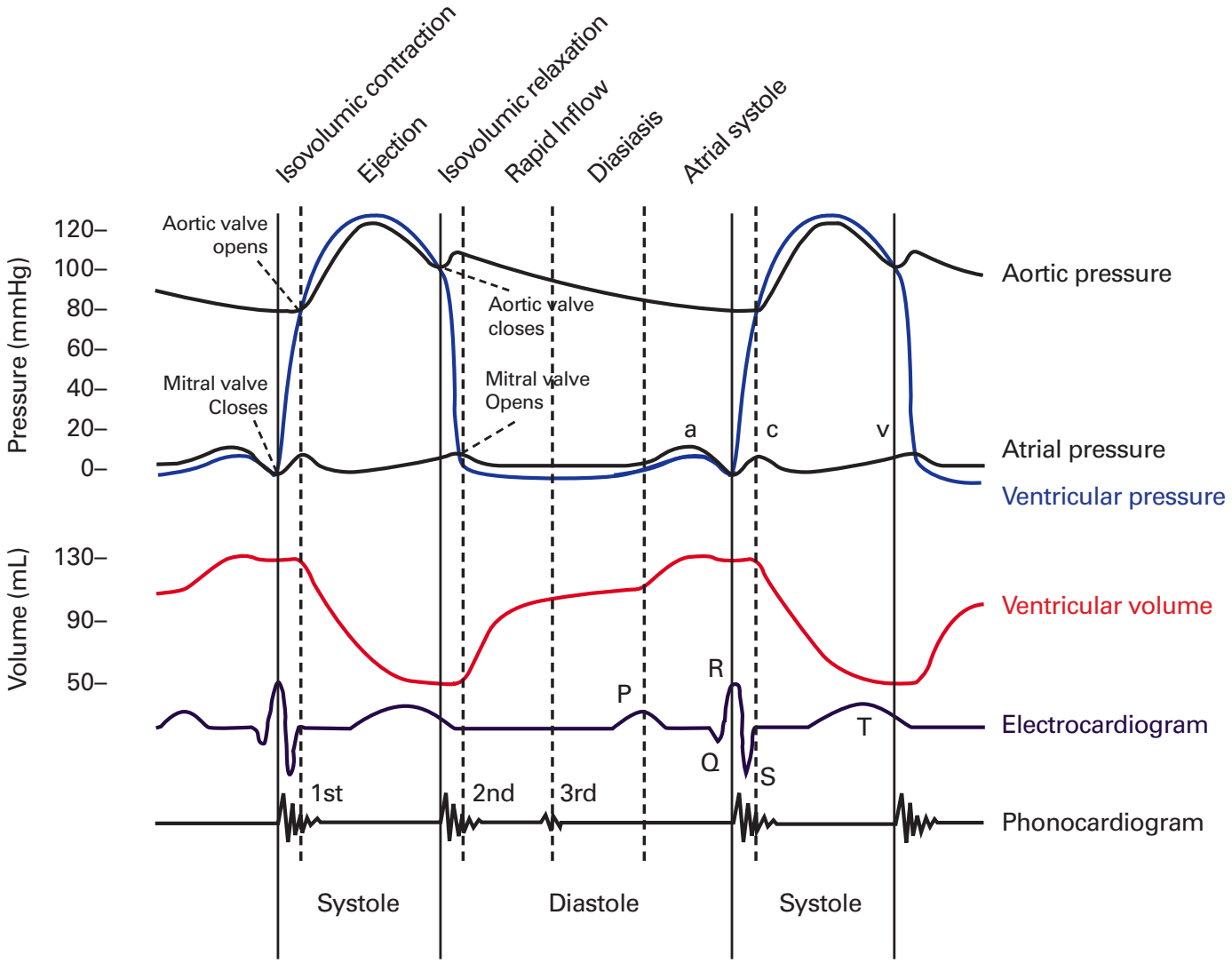


Figure 15.1 The Wigger's diagram

The atrial pressure continues to increase until left ventricular isovolumetric relaxation, when the pressure and the volume of the left atrium are nearly maximal, producing a peaked ventricular filling wave, namely the v-wave. The v-wave terminates with a rapid fall, named the y-descent, occurring when the mitral valve opens.

EXPLANATION OF THE CARDIAC CHAMBER PRESSURES

Right atrium pressure

Woods et al (2005) elaborate on the right atrial pressure as follows:

- Right atrium pressure is also known as central venous pressure

Haemdynamic wave form consists of 3 positive deflections (a, c, v-waves) and 2 negative deflections (x and y waves)

- a-waves: caused by rise in atrium pressure during atrium contraction
- c-waves: caused by closure tricuspid valve. The closure causes a small increase in atrium pressure. Not always present, as the larger influence of the atrium can cover it up.
- v-waves: caused by atrium filling from the venous system
- x-waves: when atrium contraction is completed and ventricular contraction begins, the pressure in the atrium begins to

fall. This is represented by the x-wave.

– y-wave: Tricuspid valve opens and movement of the blood from atrium to ventricle lowers atrial pressure. This is represented by the y-wave.

– **Normal RA pressure: 0 - 8 mmHg**

a-wave: 2 - 10 mmHg

v- wave: 2 - 10 mmHg

- No a-waves present in atrial fibrillation
- High a-waves are found in:
  - Tricuspid stenosis
  - Pulmonic stenosis
  - Right ventricular hypertrophy
  - Pulmonary hypertension
- High v-waves and no x-waves are seen in tricuspid insufficiency

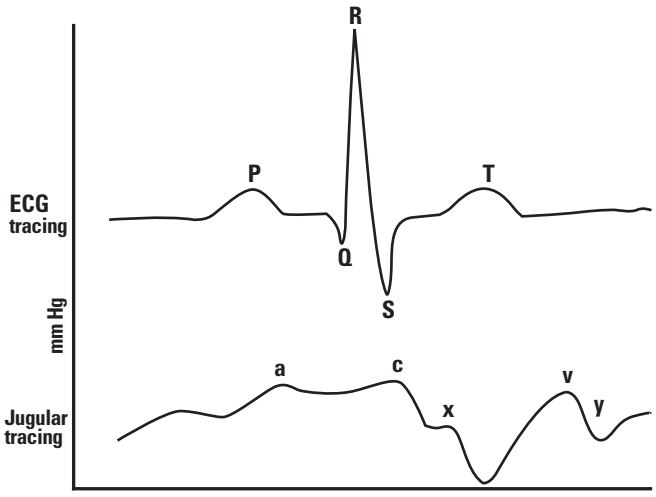


Figure 15.2: The right atrium wave form

Right ventricle pressure:

Alspach (1991) describes right ventricular pressure as:

- The pressure represented by the amount of blood in right ventricle when the healthy tricuspid valve is closed
- Mechanical systole begins at the end of the QRS- complex
- End diastolic pressure is noted; EDP shows how well the ventricle is filling (also indicates how well the patient is hydrated and how elastic the myocardium is)
- Peak systolic pressure indicates whether the RV has normal contractility and whether it is pumping into a normal or abnormal pulmonary artery bed
- High peak systolic pressures can be caused by:
  - Pulmonary congestion due to left heart failure or mitral stenosis
  - Primary pulmonary hypertension
  - Pulmonic valve stenosis
  - Left to right shunt
  - COPD
  - Normal peak systolic pressure: 15 – 30 mmHg
- High end diastolic pressures can be caused by:
  - Pulmonary valve insufficiency
  - Restrictive myocardial disease
  - Endocardial fibrosis
  - Constrictive pericarditis
  - Cardiac tamponade
  - Normal end diastolic pressure: 0 – 8 mmHg

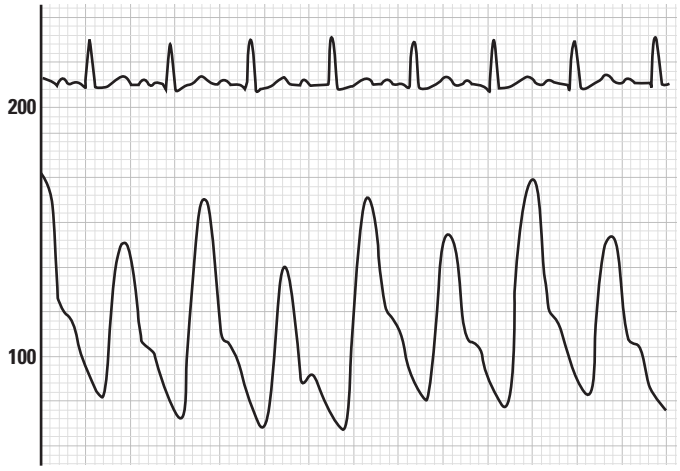


Figure 15.3: The right ventricle wave form

Pulmonary artery pressure:

Carlson (2009) elaborates on pulmonary pressure in the following manner:

- Pulmonary artery pressures consists of pressures in the pulmonary artery during diastole and systole
- The pressure in the pulmonary artery does not approach zero during diastole. The pulmonic valve closes as the pressure in the ventricle falls below that in the artery.
- High pulmonary pressures are found in:
  - Pulmonary emboli
  - Mitral valve stenosis
  - COPD
  - Pulmonary hypertension
  - Left ventricular failure
- Low pulmonary artery pressures are found in:
  - Pulmonic valve insufficiency
  - Normal pulmonary artery pressure: 15 – 30 mmHg

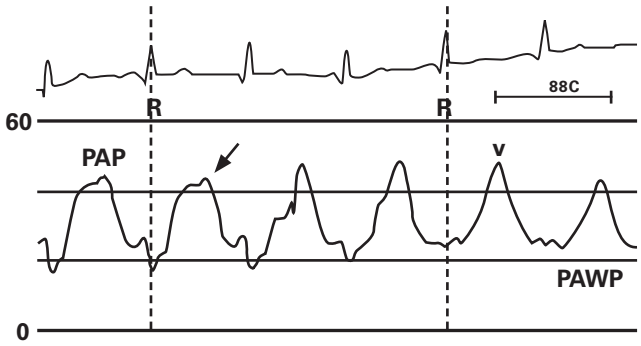


Figure 15.4: The pulmonary artery wave form

Pulmonary capillary wedge pressure:

Urden (2006) explains pulmonary capillary wedge pressure (PCWP) in the following manner:

- The objective is to measure the pressure on the left side of the pulmonary tree
- The pressure distal to the arteriolar segment of the pulmonary circulation is equal to the left atrium pressure in the absence of an obstacle between the pulmonary arteriole and left atrium (pulmonary vein stenosis or pulmonary embolism)
- The pulmonary capillary wedge pressure (PCWP) is a good approximation of the left atrium pressure and is used to assess LV filling pressures
- The PCWP will not reflect the left atrium pressure if there is pulmonary venous obstruction
- Low PCWP is found in:
  - Hypovolemia
  - Afterload reduction in the use of vasodilators

- High PCWP is found in:
  - Left heart failure
  - Mitral insufficiency/stenosis
  - Pericardial tamponade
  - Hypervolemia
  - Ischemia
  - Obstructive and restrictive cardiomyopathies
  - Normal PCWP: 2 – 10 mm Hg

Following the procedure, the venous sheath is removed and a padded dressing applied to puncture site

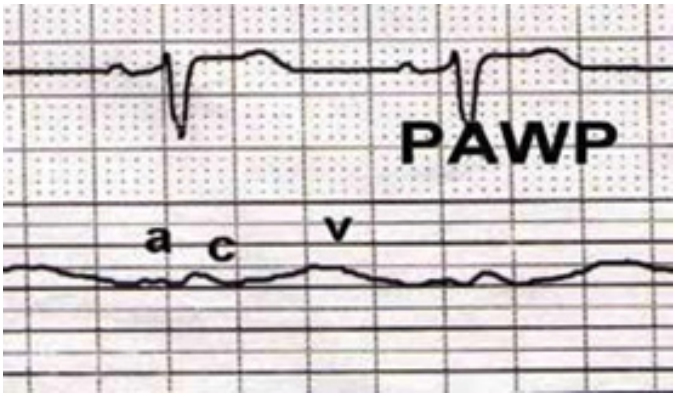


Figure 15.5: The pulmonary artery wedge pressure

GUIDELINES FOR THE REGISTERED NURSE WHEN ASSISTING WITH THE RIGHT HEART CATHETERISATION PROCEDURE:

- Ensure a sterile field
- Perform skin preparation with Iodine or Hibitaine 70%
- Routes used for catheter placement:
  - Right or left jugular vein
  - Right or left subclavian vein
  - Right or left femoral vein
  - Right or left antecubital fossa
- A pulmonary wedge catheter or multipurpose catheter can be used for the procedure
- Inflate the balloon (pulmonary wedge catheter) with helium gas prior to procedure to ensure that an intact balloon is used (Inflate balloon with helium gas if an ASD (atrial septal defect) or VSD (ventricular septal defect) or any paediatric procedure
- The skin is anaesthetised with lignociane 2%
- Venous cannulation is done and guide wire fed under fluoroscopy
- Venous introducer sheath inserted and catheter passed through this
- Once catheter is visualised in right atrium, balloon is inflated and all pressures recorded as balloon catheter follows through to RV, pulmonary artery and eventually pulmonary capillary
- Using heparinised syringes, blood specimens are taken in aforementioned anatomical positions, and O2 saturation levels are done on these samples. O2 saturation levels are done to diagnose intra-cardiac shunting
- Following the procedure, the venous sheath is removed and a padded dressing applied to puncture site

Table 15.1: A summary of the chamber pressures

	SYSTOLIC	END DIASTOLIC	MEAN	a-wave	v-wave
RA	-	-	0 - 8	2 – 10	2 – 10
RV	15 - 30	0 – 8	-	-	-
PA	15 - 30	3 – 12	PA 9 - 16	-	-
PCW	-	-	1-Dec	3 – 15	3 – 12
LV	100 - 140	3 – 12	PCW 1 - 12	-	-
AORTA	100 – 140	60 – 90	70 – 105	-	-

COMPLICATIONS ASSOCIATED WITH RIGHT HEART STUDIES:

- Pneumothorax
- Infection
- Haemorrhage
- Ventricular Dysrhythmias
- Pulmonary artery rupture
- Pulmonary artery perforation
- Pulmonary infarction
- Air emboli
- Clot formation at end of catheter
- Valvular rupture
- Septal rupture
- Chordae tendinea rupture
- Pericardial tamponade
- Knotting of the catheter in the heart chambers
- Pulmonary hypertensive crisis (children)

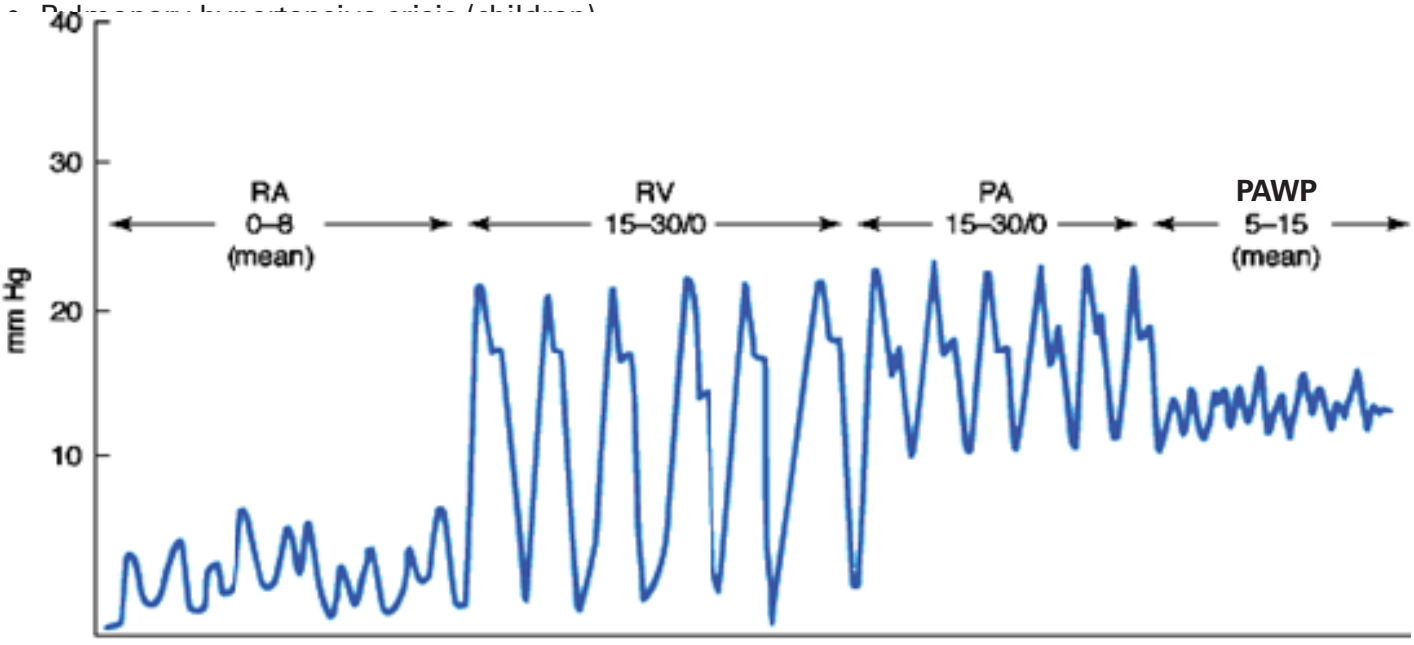


Figure 15.6: A summary of the right heart pressures

Figure 15.6: A summary

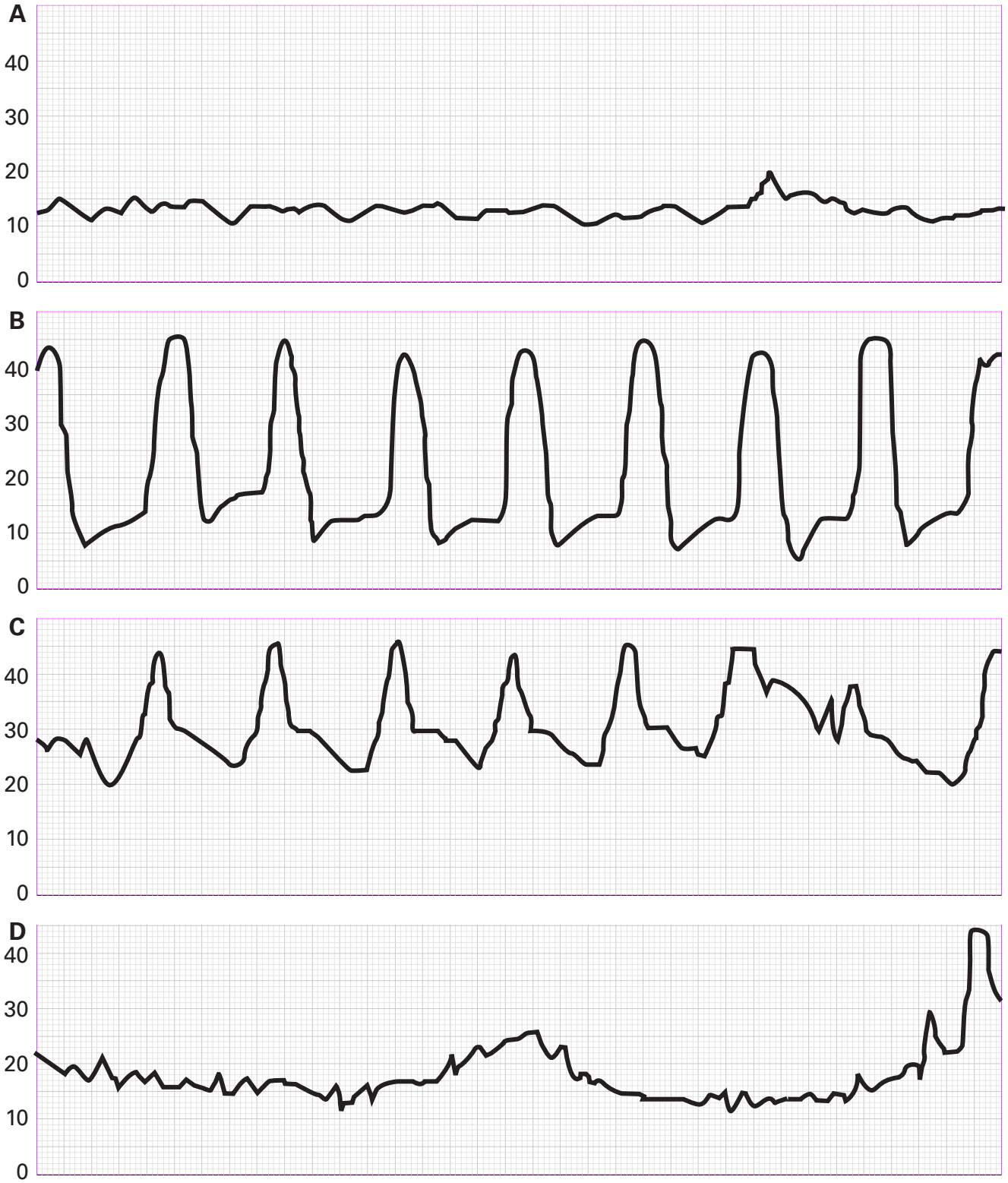


Figure 15.7: Presentation of the right heart pressure wave forms

A. Right atrium wave form
B. Right ventricle wave form
C. Pulmonary artery wave form
D. Pulmonary occlusion wave form ("wedge pressure")

This Module is Linked to a CPD Accredited Online Questionaire at www.sasci.co.za

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