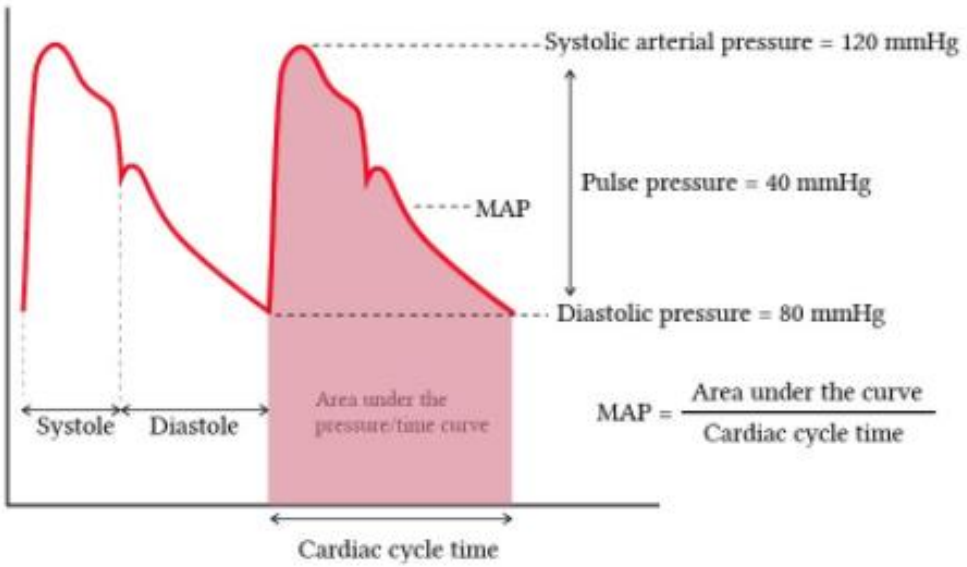
Arterial Blood Pressure Monitoring



A Learning Resource for ICU and SHDU Nursing Staff

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Indications for arterial blood pressure monitoring

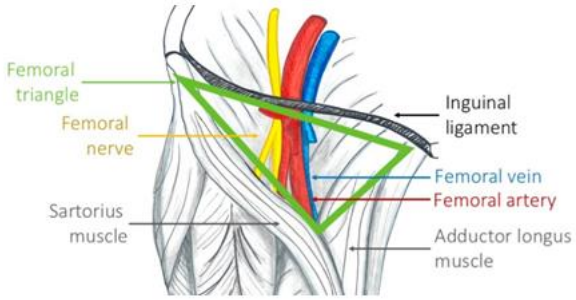
- Any major medical or surgical condition that compromises cardiac output, tissue perfusion or fluid volume status
- Patients requiring continuous monitoring of blood pressure due to difficulties in obtaining blood pressure recordings using non-invasive methods
- When frequent arterial blood gas sampling is required
- When inotropes and/or vasopressors are required

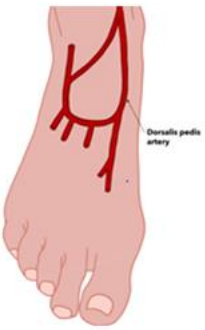
Advantages of invasive blood pressure measurement

- Invasive blood pressure measurement allows beat-to-beat blood pressure monitoring, a visible waveform, allowing a more detailed analysis of the patient's cardiovascular system to be made
- Indirect techniques can often underestimate/overestimate pressure recordings. Cuff pressures also lose accuracy in the presence of shock, arrhythmias, vasoconstrictor drugs or calcified arteries

Insertion sites for arterial cannulation

1. Radial artery – most commonly used
2. Axillary artery – this becomes the brachial artery at the level of the *teres major* muscle
3. Brachial artery
4. Femoral artery
5. Dorsalis pedis artery





Arterial catheters

Leader cath

Flow-switch

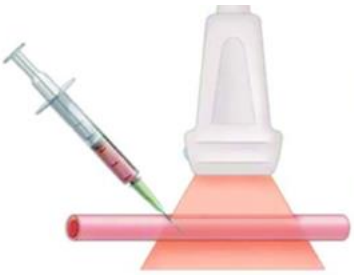
Equipment needed for arterial line insertion

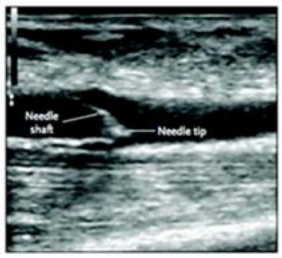
Arterial catheter placement requires at least one assistant for helping with non-sterile tasks or administering sedation during the procedure

- Arterial catheter
- Dressing pack
- Sterile drapes
- Sterile gloves
- 5 or 10ml syringe
- Ampoules containing 0.9% sodium chloride
- Chloraprep
- Suture
- Transparent occlusive dressing
- Local anaesthetic may be used
- Sonosite ultrasound guidance may be used
- The transducer flush system must be primed and available before insertion of the catheter

Techniques for insertion

- Catheter-over-needle
- Seldinger
- Modified Seldinger

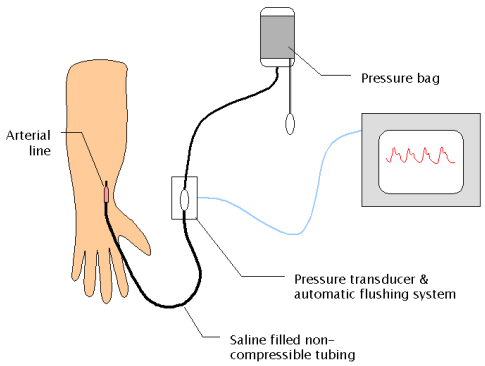




Once the arterial catheter is inserted the transducer flush system is checked to ensure that it is free from air bubbles and then securely connected to the catheter. The transducer then needs to be zeroed and levelled – see page 4

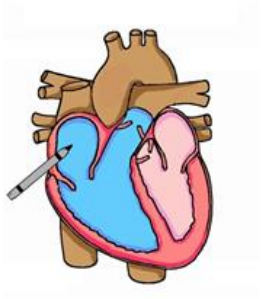
The arterial blood pressure monitoring system consists of 4 main parts

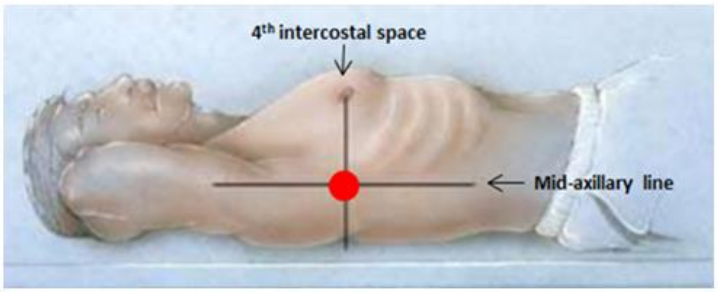
1. An indwelling arterial catheter
2. A transducer which receives the signal from the tubing and converts it into electrical energy to produce the arterial waveform
3. A pressurised flush system which helps keep the arterial catheter patent
4. Bedside monitor that displays the arterial waveform



Levelling the transducer

The transducer is zeroed and placed level with the heart at a known reference point referred to as the phlebostatic axis





The right atrium is used as a reference point and is estimated to be at the phlebostatic axis. The axis relates to the intersection of two imaginary lines. One line is at the level of the 4th intercostal space whilst the other runs mid-axillary. The cross-point (red dot shown in the above image) is where the transducer is levelled

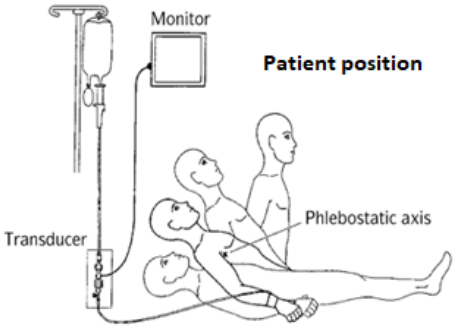
Zeroing the transducer

Once the pressurised flush system is connected to the arterial catheter – the system needs to be zeroed

- Identify the phlebostatic axis
- Turn the 3-way tap off to the patient – this is the 3-way tap nearest the transducer and then remove the cap from the 3-way tap port
- Press the zero key on the monitor → look for the display indicating that zeroing has occurred
- Replace the cap on the 3-way tap and turn the stopcock back on to the patient
- Observe the waveform and arterial pressure measurements

Frequency for zeroing the transducer

- Following insertion of the arterial catheter
- At the beginning of every shift
- When the transducer set is changed
- If there is any doubt around the displayed recordings
- Whenever the patient's position is changed



Patient position

- If the patient is lying on their side, it is more difficult to determine the exact/true phlebostatic axis
- For this reason, measurements are not as considered as accurate in lateral positons compared to those taken with a patient positioned supine

Difficulty with zeroing the transducer

- Check all equipment and connections between patient and monitor. Check that the sensor cable is securely connected to the transducer base.
- Ensure all roller clamps are open and 3-way taps in the correct position. Check system for air bubbles and clots

Safety measures

- Prime the transducer flush administration set before the arterial line is inserted
- The transducer flush administration set is always primed using a 500ml bag containing 0.9% sodium chloride as prescribed – never use any other solution. The transducer flush solution must also be checked by 2 registered nurses. Further checks should be made at regular intervals and at key points e.g. shift handover/patient transfer from another area
- The flush administration set must be free from air including the dead space in the 3-way tap ports. Ensure all connections are taut and secure especially the connections on either side of the transducer. All ports are sealed using red coloured dead end caps as these can help prevent wrong-route errors
- As soon as the arterial line is inserted → fast-flush the transducer administration set once more to ensure that the line doesn't contain any air bubbles. Promptly connect the free end of the transducer tubing to the arterial line as this will help reduce blockage of the newly inserted device. Ensure that the pressure infuser is inflated to 300 mmHg (adults) or 150 mmHg (paediatrics)
- Check the volume remaining in the transducer flush bag at regular intervals and especially during night time hours when lighting/visibility is reduced. Connect a new bag of fluid as appropriate. Never allow the fluid bag to run empty as this may result in a blocked arterial line
- On occasions the arterial line may develop a small clot. If this occurs → connect a 5ml or 10ml syringe to the 3-way tap and try to aspirate the clot
- The arterial line can only be flushed using 0.9% sodium chloride. Never inject intravenous medications into the arterial line. The consequence of accidental injection will depend on what has been injected but has the potential to cause cardiac arrest. For this reason, arterial infusion lines must be clearly identified → a red coloured dead end cap is always secured to the arterial line 3-way tap
- The transducer flush administration set is changed every 96 hours
- The arterial line dressing is also changed every 96 hours. A sterile dressing pack is used when changing the dressing. The site is examined for any redness or inflammation and is cleansed using chloraprep, and a new transparent occlusive dressing is applied. The nurse completes the arterial line bundle
- Stitches – the arterial line may or may not be sutured to the skin. If it is not sutured → highlight 'arterial line not sutured' in the alert box on the ICU observation chart
- If the arterial line is no longer required → remove it immediately

Observe for signs of arterial catheter displacement and inform medical staff

- Lack of a normal arterial waveform
- Swelling
- Haematoma
- Bleeding
- Fluid leakage
- Blanching or delayed capillary refill
- Pain, discomfort, numbness or paraesthesia

Arterial Line Bundle		
Date inserted:	Day no:	Position:
Dressing due:	Flush lines due:	
Is arterial site free from inflammation/discharge?		Y/N
Is dressing intact?		Y/N
If dressing changed was Chloraprep used?		Y/N
Is "Due changed" sticker in place?		Y/N
Hand hygiene applied prior to any arterial line interventions?		Y/N
A-line secured: Stitches ☐ Tegaderm ☐ Both ☐		
Fluid level checked in flush bag Yes ☐		
Flush lines changed every 96 hours Yes ☐ N/A ☐		
New arterial line inserted today: Y/N		
Position of new line:		

The arterial catheter is removed in the following situations

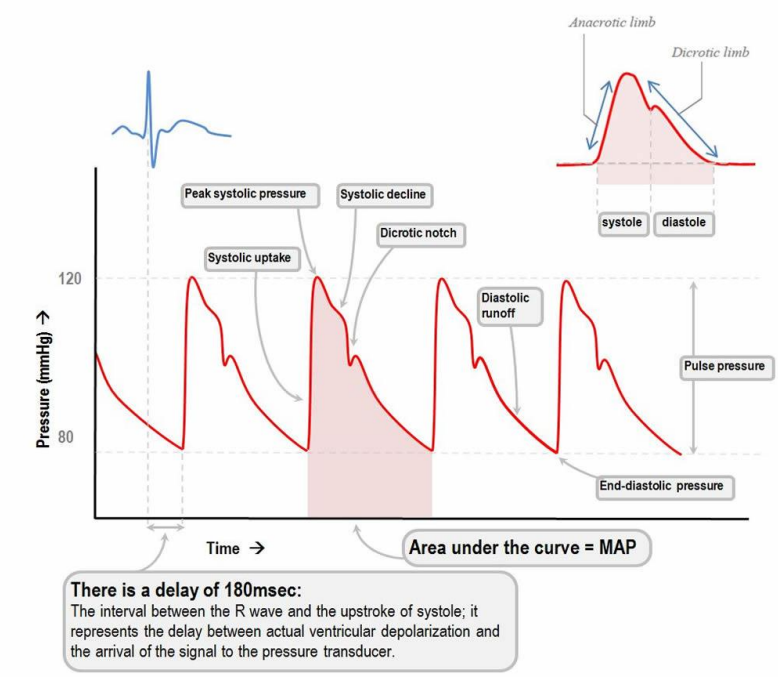
- Whenever limb perfusion is compromised
- When it is no longer possible to withdraw blood from the cannula despite troubleshooting
- When it is no longer possible to recover a normal arterial waveform despite troubleshooting
- Whenever local signs of infection are observed → obtain surface swab and send to microbiology and remove arterial cannula as directed by medical staff
- When invasive blood pressure monitoring or frequent blood sampling is no longer required

Removing the arterial catheter

- Confirm that medical staff request removal of arterial cannula
- Adhere to hand hygiene, local infection control policies and collect equipment required
- Equipment: dressing trolley, sterile dressing pack, chloraprep, stitch cutter, gauze, transparent occlusive dressing
- Close the roller clamps on the transducer fluid bag
- Using aseptic technique cleanse the arterial site with chloraprep and remove any retaining sutures
- Position gauze over the insertion site and gently withdraw the arterial cannula
- Maintain direct pressure over the arterial puncture site for at least 5 minutes. Carefully check the site at 5 minutes and reapply steady pressure for longer if oozing is observed. Inadequate pressure can result in haemorrhage or haematoma
- When bleeding has stopped → apply a small piece of folded gauze and secure over site using a transparent occlusive dressing

Normal arterial waveform

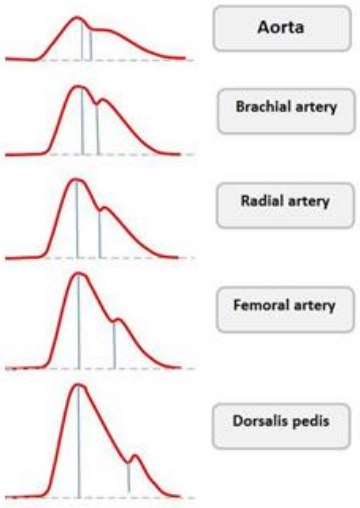
- Begins with a sharp rise
- The sharp rise represents ejection of blood from the left ventricle
- The rounded top represents systolic blood pressure
- The force of contraction diminishes and the pressure drops
- The slight upswing of the waveform is referred to as the dicrotic notch and represents closure of the aortic valve
- The downward slope after the dicrotic notch is the lowest point in diastole
- The area under the curve is the mean arterial pressure (MAP)



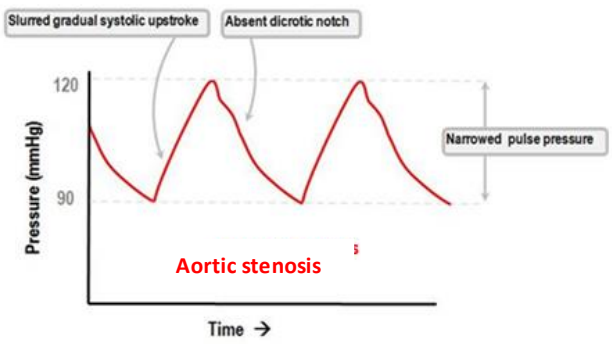
The position and prominence of the dicrotic notch may vary depending on the site of insertion

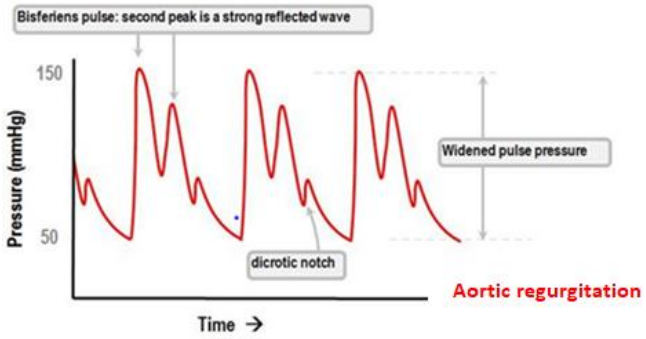
The further away from the aorta

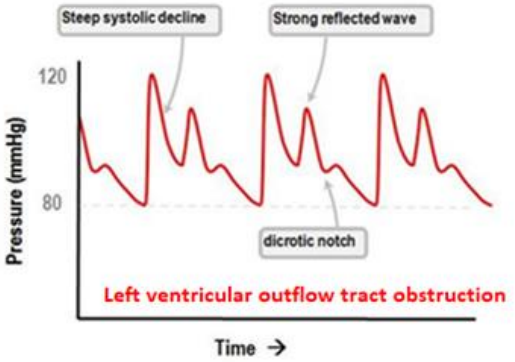
- The taller the systolic peak
- The further the diastolic notch
- The lower the end-diastolic pressure
- The later arrival of the pulse

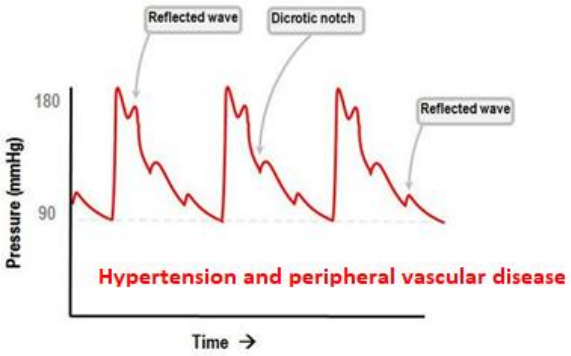


Arterial waveforms in some underlying medical conditions









The damped arterial waveform

- A damped arterial waveform is a blunted trace usually with a low systolic and high diastolic reading but mean arterial pressure often remains the same
- Anything that reduces energy in the transducer system will reduce the amplitude of the oscillations. This is termed “damping”
- Some degree of damping is needed in all systems (‘critical damping’) but if excessive, the output will be adversely affected
- Excessive damping is referred to as over-damping
- Insufficient damping is referred to as under-damping
- Most damping arises from friction in the fluid pathway

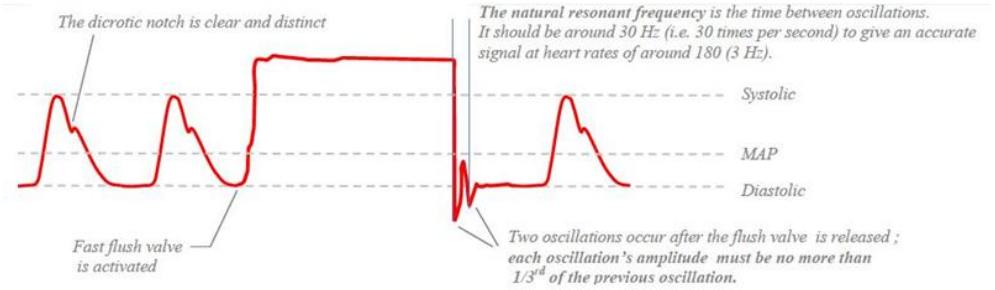
Damping can be caused by

- Kinks in the arterial catheter or arterial line
- Blocked line (clot) or air bubbles in the arterial line
- 3-way taps
- Patient factors e.g. tachycardia or high cardiac output states

Restoring the accurate undamped trace using the square wave test

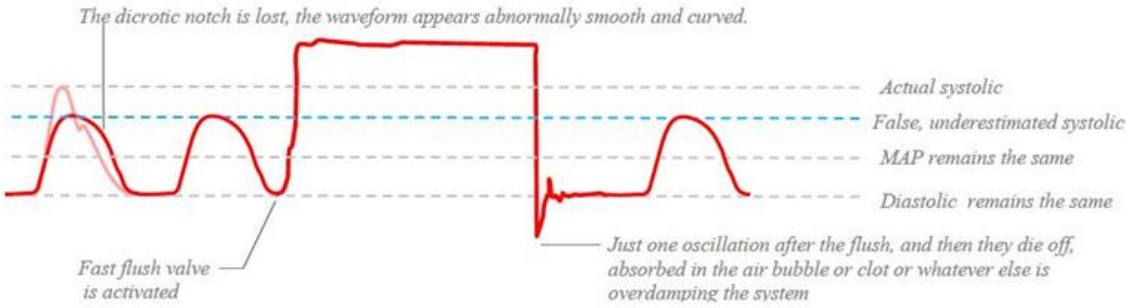
The square wave test is used when damping is visible

- When the fast flush valve is squeezed, the transducer receives a surge of the pressurised saline. This produces a waveform that rises sharply, plateaus and drops off sharply when the flush valve is released again
- This is the "square wave". The accurate, responsive adequately damped waveform is displayed
- A good arterial waveform has a distinct dicrotic notch, and after the fast flush test there are just 2 oscillations



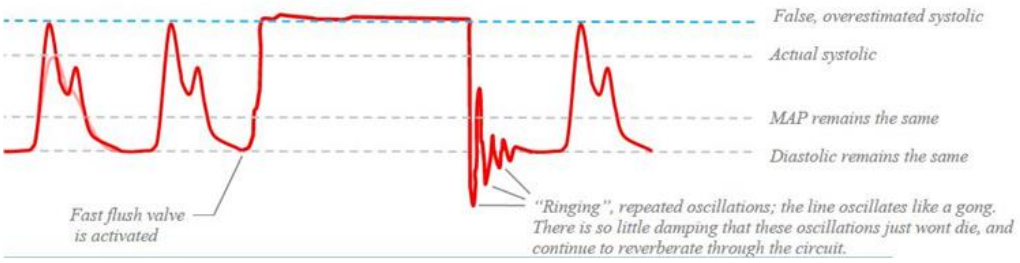
The over-damped arterial waveform

- The over-damped trace will lose its dicrotic notch, and there won't be more than one oscillation
- This happens when there is a clot in the catheter tip, or an air bubble in the tubing
- Over-damping lowers the systolic pressure



The under-damped arterial waveform

- The under-damped trace will overestimate the systolic pressure and there will be many post-flush oscillations
- An under-damped trace is often characterised by a high initial spike in the waveform
- The MAP remains the same in spite of damping

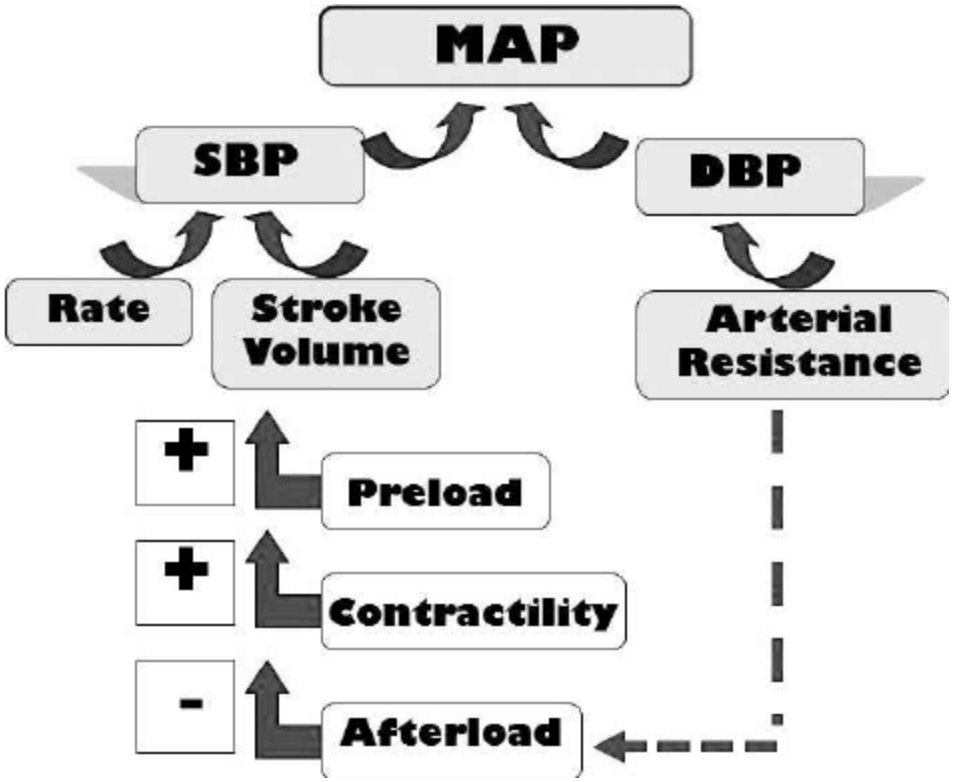


Blood pressure

- Normal adult blood pressure range: from 100/60 mmHg to 140/90mmHg.
- Systolic pressures vary between 100 and 140mmHg
- Diastolic pressures may range between 60 and 90mmHg
- A resting diastolic pressure persistently exceeding 90mmHg would indicate hypertension
- The mean arterial pressure (MAP) is more crucial as it is the pressure/real 'driving force' which pushes blood through the systemic circulation

Mean arterial blood pressure (MAP)

- Mean arterial pressure = (diastole x 2) + systole ÷ 3
- Defined as the average arterial blood pressure during a single cardiac cycle
- MAP is influenced by cardiac output and systemic vascular resistance, each of which is influenced by several variables
- Reflects haemodynamic perfusion pressure of the vital organs
- A MAP of at least 60mmHg is necessary to perfuse the coronary arteries, brain, and kidneys
- Normal range is approximately 70 to 110mmHg
- Aim for mean arterial pressure ≥ 65mmHg



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Arterial blood gas sampling

Accurate results for an arterial blood gas (ABG) depend on the proper manner of collecting, handling and analysing the specimen. ABG measurements are particularly vulnerable to sampling errors and can produce incorrect blood results. It should be recognised that sampling is risky, prone to contamination and should only be done by appropriately trained staff

Sampling errors

- Air in the sample: any air bubble in the sample must be expelled as soon as possible after withdrawing the sample and before mixing with heparin or before any cooling of the sample has been done
- Inadequate removal of flush solution in arterial lines prior to blood collection. Staff should be aware of the volume of system dead-space. This means that 2ml of fluid should be discarded when sampling from the distal 3-way tap
- Insufficient mixing of heparin in the syringe after blood is drawn. Avoid this by mixing the blood sample thoroughly be inverting the syringe up to 10 times and rolling it between the palms of the hand
- A delay in specimen transportation/delayed analysis of a non-cooled sample: ABG samples may need to be sent to the labs/other ward areas on a few occasions (e.g. if unit blood gas machine is faulty). Samples that are sent to the lab or other ward areas should have the correct patient identification label and the sample should be transported in a bag of ice. Lab staff should be informed in advance of the ABG sample being sent
- Missing or wrong patient/sample identification

Indications for obtaining an arterial blood gas

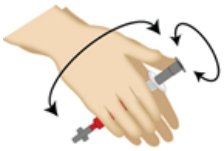
- Monitoring acid-base abnormalities and response to changes in ventilation
- Changes in monitored respiratory variables e.g. oxygen saturation or end-tidal CO_2
- Monitoring of electrolytes and glucose
- Monitoring of bleeding or coagulation tests
- When citrate anticoagulation is used during continuous renal replacement therapy

Equipment needed for collecting the ABG sample

- Gloves and apron
- Heparinised blood gas syringe with cap
- A 2ml or 5ml syringe
- Alcohol swab
- Sterile gauze
- Red cap
- Patient ID label to place on the ABG syringe

Procedure for obtaining an arterial blood gas sample

- Wash hands and apply gloves and apron
- Remove the red cap from the 3-way port and clean the port with the alcohol swab
- Connect 2ml syringe to the hub. Turn the 3-way tap ON to the artery and OFF to the transducer
- Withdraw 2ml of blood or until the dead-space volume from the arterial catheter is removed
- Turn 3-way tap diagonally to close OFF artery, port and transducer
- Connect the blood gas syringe and withdraw blood slowly. Check that there is no air in the syringe and gently mix the sample using the 'rock and roll' method immediately.



- Turn 3-way tap OFF diagonally to the artery, port and transducer and then remove the ABG syringe. Place green coloured cap on the ABG syringe and attach patient ID label

- Turn 3-way tap ON to the transducer and artery and then squeeze the flush device actuator to clear the line completely of blood
- Turn 3-way tap ON to the port and the transducer and then flush the port clear of blood onto the piece of sterile gauze
- Replace with a clean red cap
- Turn 3-way tap on to transducer and artery and check arterial pressure waveform
- Dispose of waste materials

Using the arterial blood gas analyser

- Only staff that have received the appropriate training can operate the blood gas analyser
- An operator identifiable barcode is issued when training is completed
- This barcode must not be shared with others
- Always wear gloves when handling/transporting ABG samples
- Select the appropriate sample type e.g. arterial, venous, micro
- Check and confirm patient ID
- Dispose of ABG syringe into the sharps disposal container provided
- Remove and dispose of gloves
- Wash hands
- Record ABG results on the ICU chart

If ICU ABG analyser is out of order

- If transporting the ABG sample to another department for analysis → ensure the green coloured cap is connected to the ABG syringe and make sure the sample is kept moving by gently rolling it between the palms of the hand

Preventing and troubleshooting arterial line problems

Problem: Haemorrhage or accidental removal of arterial line

Potential causes: Loose connections and unstable security of arterial line are likely causes. Retaining sutures may not always be in place or adhesive strips may not be adequately securing the cannula to the skin.

Action: Immediately turn off the 3-way tap nearest the cannula and check the patient's vital signs, then undertake the following –

- Ensure all transducer connections are taut and secure. Whilst the 3-way tap nearest the cannula remains in the 'off' position, remove the cap and using the flush device, flush the line to ensure that all air/clot is removed from the system
- If retaining sutures are loose → inform medical staff as new sutures may be needed. Alternatively, use IV tegaderm dressing & use the adhesive strips to secure the 'wings' of the arterial cannula to the skin
- Ensure the arterial monitor alarm is on so that any accidental disconnections will be rapidly alerted and promptly treated
- If the arterial line is removed → apply firm pressure to the puncture site for at least 5 minutes or until bleeding has stopped

Problem: Loss of waveform, abnormal waveform, dampened waveform, inaccurate readings

Action:

- The arterial catheter may have migrated against vessel wall → the waveform may be restored by repositioning the affected limb
- Arterial catheter may be kinked → remove the dressing and inspect the insertion site
- Baxter arterial cannula with flow-switch → check that the flow-switch is not in closed/locked position
- Check the transducer set → roller clamps should be open and 3-way taps should not be turned off. Check the transducer set for any kinks
- Sensor cable → check that the sensor cable has a secure connection to the transducer base
- The Pressure infuser bag may have lost it inflation pressure → check inflation pressure and maintain inflation at 300mmHg
- Check the volume remaining in the bag of saline inside the pressure infuser → never allow the infusion solution to empty. Failure to replace the infusion solution means that the cannula will not receive any flush to maintain its patency and risk complete occlusion of the arterial catheter. Ensure adequate ambient lighting to inspect the flush system particularly during night time hours or where lighting is reduced
- Possible clot inside the arterial catheter → insert a syringe into the 3-way tap and gently aspirate to aid release of clot. Flush the line once the clot has been removed.
- Inaccurate readings or falsely high readings may be due to: incorrect placement of transducer, kinks, air bubbles or clots
- Perform calibration/zeroing procedure

Preventing and troubleshooting arterial line problems

Problem: Unable to aspirate blood from arterial catheter when undertaking blood sampling procedure

Action:

- Check arterial cannula for any kinks or incorrect position of the 3-way tap
- Apply gentle traction to the cannula
- Gently try to flush. Inform medical staff if unable to flush
- Arterial cannula may need to be replaced

Problem: Blanching of affected limb with arterial cannula in situ

Action:

- Immediately inform medical staff as this may indicate arterial occlusion
- Assessment should include checking for adequate circulation to the cannulated limb, inspecting skin colour, palpation of skin temperature and assessment of capillary refill time and distal pulses if appropriate
- Medical staff may request to remove the arterial line and an alternative site may be selected

Problem: Potential for drug administration errors – drugs must never be administered via arterial lines as even small doses can cause severe toxicity

Action:

- The arterial line should be clearly identified by using red caps and label accordingly.
- Transducer infusion solution: this must always be 0.9% sodium chloride. Check the infusion solution against the fluid prescription and obtain witness countersignature.

Problem: Potential for insertion site problems such as redness, swelling, leakage

Action:

- Report any concerns to medical staff and document
- Ensure adequate hand hygiene and always use gloves when handling arterial line
- If there is evidence of redness, inflammation or exudate around the insertion site → obtain wound swab and send to microbiology
- If the arterial catheter is removed for suspected infection →the distal tip of the catheter should be sent to microbiology. Record on appropriate documentation.