Instructions on the use of arterial lines

AIM: To provide guidance on the use of arterial catheters and pressure transducers
SCOPE: All adult ICUs within Royal Sussex County Hospital and Princess Royal Hospital

1. INTRODUCTION

An arterial catheter is a small cannula inserted into an artery and connected to tubing to allow for continuous blood pressure monitoring and for repeated aspiration of blood for analysis. Arterial catheter tubing includes a section known as the transducer. The transducer converts the mechanical pressure into an electrical waveform via a cable connected to a monitor. Arterial catheters set up in this fashion are commonly referred to as 'arterial lines'.

Arterial Lines are routinely used in acute settings for the monitoring of arterial blood pressure and obtaining serial blood gas measurements. Patients with arterial lines should not be nursed outside of acute areas in order to avoid associated serious complications such as limb ischaemia, haemorrhage, accidental administration of intra-arterial drugs and nerve trauma. To ensure patient safety it is essential that all staff caring for patients with arterial lines undertake competency based training.

Recommendations following a National Patient Safety Agency (NPSA) rapid response report in 2008 highlighted two deaths and 158 incidents up to June 2008. Errors included the wrong infusion fluid being administered and faulty sampling technique leading to patients being incorrectly treated. Recommendations included the development of a line labelling policy to reduce the risk of accidental drug administration, guidelines for the management of arterial lines and robust training for all staff involved in their management.

Arterial lines are routinely used in critical care areas for monitoring arterial blood pressure or serial blood gas measurements. This guidance applies to all staff in critical care, theatres and other areas such as the Emergency Department where arterial lines are inserted and managed in adult patients. Patients with arterial lines should not be nursed outside these areas, in order to avoid complications related to both care of the line and analysis of the results of arterial blood samples drawn from an arterial line. This guideline does not cover use of arterial lines in children or neonates, nor the use of invasive arterial vascular access for angiography/angioplasty in cardiac or interventional radiology settings.

Definitions

Arterial line
An arterial line is an intravascular catheter placed in a patient's artery.

Transducer
The measurement of a patient's blood pressure with a pressure transducer involves the arterial cannula being connected to a pressurised line. The pressure within the cannula is transmitted through fluid filled tubing to the transducer diaphragm. To ensure accuracy of these values the transducer should always be at the level of the right atrium (sternal notch) for all patients, bar those with traumatic brain injuries (TBI) where the transducer should be at the level of the 4th ventricle of the brain (tragus).

Zeroing the Transducer

To safely manage the arterial line it is essential to transduce the pressure within it. The transducer uses zero as a reference baseline (atmospheric pressure) and ensures an accurate measurement of the patient's blood pressure.

2. PROCESS

2.1 Documentation of clinical need for insertion

Arterial lines and arterial blood gas sampling can be associated with morbidity and mortality and so the clinical indication for the insertion of an arterial line should be documented.

2.2 Indications for the insertion of arterial lines

Continuous arterial pressure monitoring:

- Haemodynamically unstable patients
- Patients on potent vasopressor or vasodilator drugs
- Cardiopulmonary bypass
- Major vascular, thoracic, abdominal or neurological surgical procedures
- Patients supported on an intra-aortic balloon pump (IABP)
- Patients receiving intracranial pressure monitoring

Serial blood gas measurements:

- Patients in respiratory failure
- Patients being maintained on or being weaned from mechanical ventilatory support
- Patients with severe acid/base abnormalities
- Where frequent blood samples are required, e.g. to measure electrolyte concentrations

2.3 Insertion of arterial lines

Standard (universal) precautions and an aseptic non-touch technique (ANTT) must be adhered to when manipulating, accessing or removing an arterial line. When siting an arterial line an ANTT is appropriate for a standard cannula technique, but full asepsis including the use of sterile gloves should be used for arterial lines placed using a Seldinger technique. Personal protective equipment (PPE) should be worn: visors or other appropriate eye protection is advocated due to the high pressures associated with bleeding from arterial sites.

2.4 Site and procedure for insertion

Suitable sites for the insertion of arterial lines include the radial, brachial, femoral, dorsalis pedis and axillary arteries. The brachial artery lacks the benefit of collateral circulation and therefore is commonly felt to have the risk of significant distal limb ischaemia if the artery becomes occluded and should be avoided if possible. If using ultrasound to place a radial line go as distal as possible – there is an increased risk of compartment syndrome at the mid-forearm level.
The arterial line must be inserted by a doctor or other practitioner competent in the procedure. If the radial artery is selected the operator may perform an "Allen" test to assess peripheral limb perfusion distal to the proposed arterial cannula site prior to insertion.

	Recommendation (Action)	Justification (Rationale)
1	The procedure should be discussed with and explained to the patient.	
2	Doctor and assistant wash hands and put on gloves and plastic apron. Facial protection should be worn when there is a risk of splashing.	Prevents transmission of micro-organisms. Reduces risk blood borne virus transmission.
3	Prepare cannulation site, remove hair if necessary. Clean skin with 2% alcoholic chlorhexidine skin cleanser. Place disposable absorbent pad under limb. Use an aseptic non-touch technique to prevent cross infection and prevent contamination of the site for simple arterial cannula insertion. For a cannula inserted using a Seldinger technique use full asepsis and sterile gloves.	Prevents infection
4	Infiltrate cannulation site with local anaesthetic and leave to take effect.	Minimise pain during procedure, so facilitating patient co-operation
5	Assistant may need to immobilise limb.	Facilitates cannulation.
6	Insert cannula. Ultrasound can be used if cannulation is expected to be difficult as it may improve success rate.	
7	Ensure all guidewires removed - double-check with a second person.	Reduce risk of retained guidewire
8	Apply pressure to cannulated artery whilst transducer line is securely attached.	Prevents blood spillage
9	Secure cannula using transparent semi-permeable dressing, e.g:Tegaderm. Sutures may also be used where the risk of cannula displacement is deemed to be high. Secure tubing safely to limb.	
10	Ensure all sharps disposed of safely at the patient's bedside.	Prevent sharps injury
11	Remove gloves, apron and if appropriate facial protections and dispose of as clinical waste.	Universal precautions
12	Decontaminate hands	
13	Document line insertion on Clinical Information System / in patient notes.	

2.5 Identification of arterial lines

An appropriate red line connection should be used to clearly indicate that the line is arterial. The arterial line must be clearly labelled with a red sticker. Bungs should also be red to distinguish them from venous connections.

2.6 Arterial line fluid prescription

Drugs and hypertonic solutions must never be given via an arterial Line (NPSA, 2008)

Appropriate fluid is 0.9% saline. Epic3 guidelines (2014) recommend the use of sterile normal saline (no added heparin) to flush and lock catheter lumens that are accessed frequently.

The arterial line fluid must be prescribed on the patient's drug chart or Clinical Information System (CIS).

The fluid must be checked by two registered practitioners before it is connected to the arterial line, and checked at the start of each shift and on patient admission if transferred from theatres, ED or another critical care area.

2.7 The transducer system

The measurement of a patient's blood pressure with a pressure transducer involves the arterial cannula being connected to a pressurized line. The pressures in the cannula are transmitted through fluid filled tubing to the transducer diaphragm. The movement of the diaphragm is converted to a low voltage electrical signal. The signal is amplified and converted to a real-time waveform display on the monitor. The measurements are then digitally displayed in mmHg. (See Figure 1)

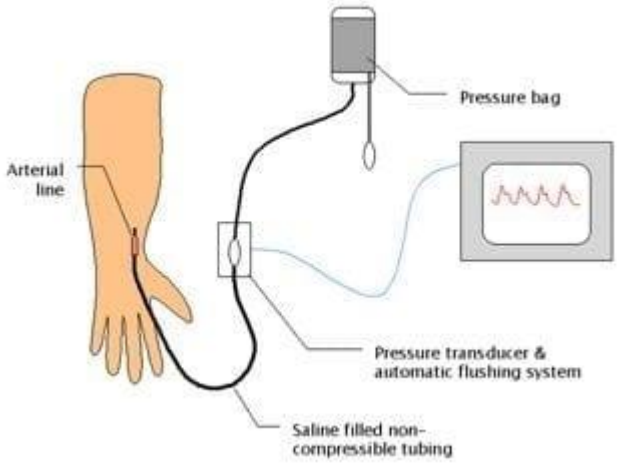


Figure 1: The pressure transducer

2.8 Setting up the transducer

	Recommendation (Action)	Justification (Rationale)
1	Before and after handling any invasive clinical equipment, hands should be decontaminated with soap and water or alcoholic hand rub. Put on gloves and apron.	Significantly reduces the number of pathogens on the hands (Larson 1995).
2	The transducer should be removed from its package and the Luer connections checked for tightness. 	The connections can be loosely packed.
3	The extension kits to allow blood sampling should be as short as possible.	Long extensions alter the pressure reading
4	A bag of 0.9% sodium chloride should be attached to the transducer set.	
5	The fluid bag label should be clearly visible through the pressure bag.	Allows for checking whilst in use
6	Label the system when set up with date and time.	To ensure it is changed as per protocol.
7	The drip chamber should be squeezed gently to fill only the bottom of the chamber.	When the bag is pressurized the drip chamber will fill higher.
8	To prime the set pull the small cord on the plastic transducer.	
9	When the set is primed the pressure bag should be fitted and inflated to 300mmHg. 	At this pressure 3 to 4 mls/hr of 0.9% sodium chloride will pass through the flush device to keep the line patent.
10	The pressure lines should be examined for air bubbles. If found they can be removed by flushing or gently tapping the set. Do not flush bubbles into the patient's artery.	All air must be removed to prevent dampening of the arterial waveform.
11	All connections should be swabbed with a 2% chlorhexidine wipe for 30 seconds then allowed to dry.	Reduces the possibility of bacterial contamination.
12	Connect the line to the arterial catheter using a non-touch technique.	Reduces bacterial contamination and protection of patient and yourself.

	Recommendation (Action)	Justification (Rationale)
13	Needle free connectors, for example red swanlocks, are strongly recommended for the blood sampling port and should be changed weekly unless the device is changed	To reduce risk of inadvertent intra-arterial administration of drugs. Reduces risk of infection.
14	The transducer should be fitted into its holder on the drip stand, levelled to the patient's sternal notch (or tragus in TBI) and the electrical lead connected to the monitor by the bedside.	A transducer set at the wrong height will produce false readings.
15	The transducer should be opened to air and zeroed to atmospheric pressure. Open the port on the transducer and zero on the monitor menu at least once per shift prior to taking a reading	The transducer must be calibrated following insertion of an arterial cannula, at the beginning of every shift and when the transducer set is changed to ensure accuracy.
16	The pre-connected bungs on the zero port of the transducer should be changed for either the white bungs provided in the set or red bungs (not swanlocks).	Air can entrain into the transducer and alter the pressure reading and/or water can leak from the hole in the pre-connected bungs which are intended for initial zeroing only.
17	Re-level the transducer each time the patient changes position or the bed is raised or lowered.	To ensure a consistent zero reference point.
18	Check that the arterial trace is satisfactorily displayed on the monitor.	This makes sure that the line is patent and the readings should be accurate.
19	Remove gloves, apron and, if appropriate, facial protection and dispose of as clinical waste.	
20	Decontaminate hands	

2.9 Care of the line and the transducer

	Recommendation (Action)	Justification (Rationale)
1	Care must be taken to ensure that the arterial line does not become disconnected	As the line is in an artery and not a vein the patient can potentially exsanguinate.
2	The waveform should be continuously displayed	The arterial trace should not be under or over damped as this will generate inaccurate readings **(see appendix 1)**.
3	The arterial line fluid should be checked against the prescription once per nursing shift.	To ensure it is visible and correct.
4	Every **third day** the transducer and flush bag should be either changed or taken down if no longer required (see label for date).	To reduce the risk of contamination and infection.
5	The cannula does not need regular flushing while on a pressure bag system, but a flush may be required to gain an arterial trace. The cannula can be flushed with the manual fast flush device. Flushing with a syringe is not advised.	Ensuring a patent line and a good waveform will provide an accurate arterial pressure reading. A flush can be used to test for “dampness” of the arterial trace **(see appendix 1)**.
6	The pressurized flush bag should be maintained at a pressure of 300mmHg. If the waveform changes check the pressure.	This will ensure that 4mls/hr of 0.9% sodium chloride will be delivered through the cannula, thereby keeping it patent, and will maintain constant pressure within the system.
7	The flush bag should be changed with the transducer or when empty.	Prevents blood spillage
8	Maintain a closed system ensuring minimal disconnection in the circuit.	To avoid contamination
9	Hand washing must be performed and personal protective equipment applied before cleaning the catheter site.	To reduce risk of infection
10	Chloraprep MUST be used to clean the catheter site during dressing changes and allow to air dry. Alternatives are available for patients with chlorhexidine allergy	To reduce risk of infection
11	**Prior to securing the line it should be curled in a “U” to prevent any direct pull on the line**	To reduce the risk of dislodgement of the line
12	The site should be secured with a sterile, moisture permeable, dressing e.g. Tegaderm. **Dressings should only be changed when soiled or when the line is being changed**	Transparent, semi-permeable polyurethane dressings should be changed every 7 days, or sooner, if they are no longer intact or if

	Recommendation (Action)	Justification (Rationale)
		moisture collects under the dressing. (epic3 guidelines (2014)
13	If the catheter is not sutured, renewal of dressings should be performed by 2 nurses.	To ensure the cannula is not dislodged during the procedure
14	The line should be observed for signs of inflammation/ infection. Arterial line care bundle must be completed once per shift if line in situ.	
15	The circulation of the cannulated limb should be continuously monitored for signs of the following • cyanosis • decreased pulse • blanched colour • cool skin/extremities • sluggish capillary refill time • bleeding • tingling or paraesthesia **Changes should be reported to medical staff.**	**The cannula must be removed if there is sustained blanching to the limb, distal to the cannula site**

2.10 Sampling from the arterial line

Staff should always ask themselves “do I need to take this sample?”

Indications include:

- Changes in monitored respiratory variables e.g. oxygen saturation or tidal volume
- Monitoring of results of changes in ventilation
- Monitoring of electrolytes
- Monitoring of bleeding or coagulation tests
- Monitoring acid/base abnormalities

Sampling from arterial lines should only be performed by staff competent in the technique.

	Recommendation (Action)	Justification (Rationale)
1	Wash hands and apply gloves and apron. Face protection is advised.	
2	Use non-touch technique at all times. Clean port with 2% PDI wipe for 30 seconds; allow to dry prior to any access. The port should have a RED needleless valve and should also be cleaned after use.	
3	Mute alarm on monitor	Prevent unnecessary noise
4	Connect 5 ml syringe to hub, turn port on to artery, off to transducer. Withdraw 3 ml of	Prevent contamination of blood sample

	Recommendation (Action)	Justification (Rationale)
	blood, or until line is clear of infusate.	with infusate
5	Turn 3 way tap diagonally to close off artery, port and transducer.	Prevent back flow of blood from artery and contamination with infusate
6	Connect either heparinised blood gas syringe or vacutainer equipment and withdraw blood slowly.	Prevent haemolysis and inaccurate results
7	Turn 3 way tap off diagonally to artery, port and transducer prior to removing syringe/vacutainer.	
8	Turn 3 way tap on to transducer and artery and pull flush device actuator to clear line completely of blood.	Blood is a rich culture medium and so reduction of infection risk
9	Turn 3 way tap on to port and transducer and flush port clear of blood into a new 5ml syringe.	
10	Clean port with 2% PDI wipe	
11	Turn 3 way tap on to transducer and artery.	
12	Dispose of waste materials, remove gloves and apron and wash hands	

2.11 Arterial blood gas measurement

A blood gas analyser should only be used by, or under the supervision of, someone suitably trained in its use.
Any air must be expelled immediately from the blood gas syringe as this will alter the results. Results should be recorded either on the patient's chart or electronic record.

Unexpected results should be discussed with the shift leader or medical staff as soon as possible and documented in the patient's health records. The possibility of contamination should always be considered.

2.12 Causes of inaccurate measurements

Pressures

- System not levelled/zeroed
- No fluid/ Pressure in flush bag
- Wrong tubing used.
- Bubbles in tubing
- Limb or patient position
- Cannula position
- Arrhythmias
- Size of cannula

Sample results

- Air or excess heparin in syringe
- Inadequate clearance of infusate
- Wrong infusate and inadequate clearance
- Delay in analysis
- Haemolysis due to rapid withdrawal

2.13 Removal of arterial lines

Arterial lines should be removed when no longer required, if limb circulation is compromised, if the cannula is misplaced, or if there are signs of local infection. As arterial pressure is greater than venous pressure a longer period of pressure is required over the cannula site in order to prevent haematoma formation.

Pressure must be applied aseptically over the site until there is no further evidence of bleeding or tissue swelling.

Extra care and pressure should be applied to patients with a coagulopathy, and consideration of additional limb and arterial site observations.
Removal of arterial lines should be carefully documented in the notes or Clinical Information System.

2.14 Potential Complications of arterial lines

- haematoma/bleeding at the puncture site
- arterial spasm or occlusion with compromise in circulation distal to the site
- air emboli
- cannula tip dislodgement or puncture of arterial wall by cannula tip
- nerve damage
- extravasation
- site infection/abscess
- arterio-venous (A/V) fistula formation
- pseudoaneurysm formation
- catheter embolism
- catheter associated bacteraemia

3. REFERENCES

AABGI Safe Vascular Access 2016
http://www.aagbi.org/sites/default/files/Safe%20vascular%20access%202016.pdf

Bernsten AD, Soni N, Oh T E, 2003 Oh's Intensive Care Manual 5th Edition p80-81 Butterworth Heinemann

Department of Health (DoH), 2008. Clean, Safe Care – Reducing Infections and Saving Lives

Arterial line dynamic response testing | Deranged Physiology

Dougherty L, Watson J (2008) Vascular access devices: insertion and management Dougherty L, Lister S in: The Royal Marsden Hospital Manual of Clinical Nursing Procedures 7th Edition. Oxford, Wiley-Blackwell.

EPIC3 (Evidence based Practice in Infection Control), 2014 National evidence-based guidelines for preventing Healthcare-associated infections in NHS Hospitals in England, Journal of Hospital Infection, 86S1, S1-S70

Ewans B, Jevons P (2007) Monitoring the Critically Ill Patient 2nd Edition. Oxford, Blackwell Science.
Kirchhoff KT, Rebenson-Piano M, Patel MK 1984 Mean arterial pressure readings: variations with positions and transducer level. Nurs Res. 1984 Nov-Dec; 33(6):343-5.

McGee W, Headley J and Frazier J (eds.) (2008) "Quick Guide to Cardiopulmonary Care." Second edition. Edwards Life Sciences. Irvine California

National Patient Safety Agency (NPSA) (2008a) Rapid Response Report NPSA/2008/RRR006 Problems with infusions and sampling from arterial lines. London, NPSA. NB: updated reference

Plowright C, Sumnall R (2022) Essential critical care skills 3: arterial line care. Nursing Times {online]; 118: 1, 24-2

Pratt, R.J et al 2007. Epic 2; National Evidence-Based Guidelines for Preventing Healthcare-Associated Infection in NHS Hospitals in England.
http://www.epic.tvu.ac.uk/PDF%20Files/epic2/epic2-final.pdf

Singer M, Webb AR (2009) Oxford Handbook of Critical Care 3rd Edition. Oxford, Oxford University Press.

Traoré O, Liotier J, Souweine B. 2005 Prospective study of arterial and central venous catheter colonization and of arterial- and central venous catheter-related bacteremia in intensive care units. Crit Care Med. 2005 Jun; 33(6):1276-80

Woodrow P (2009) Arterial catheters: promoting safe clinical practice. Nursing Standard 24 (4): 35-40.

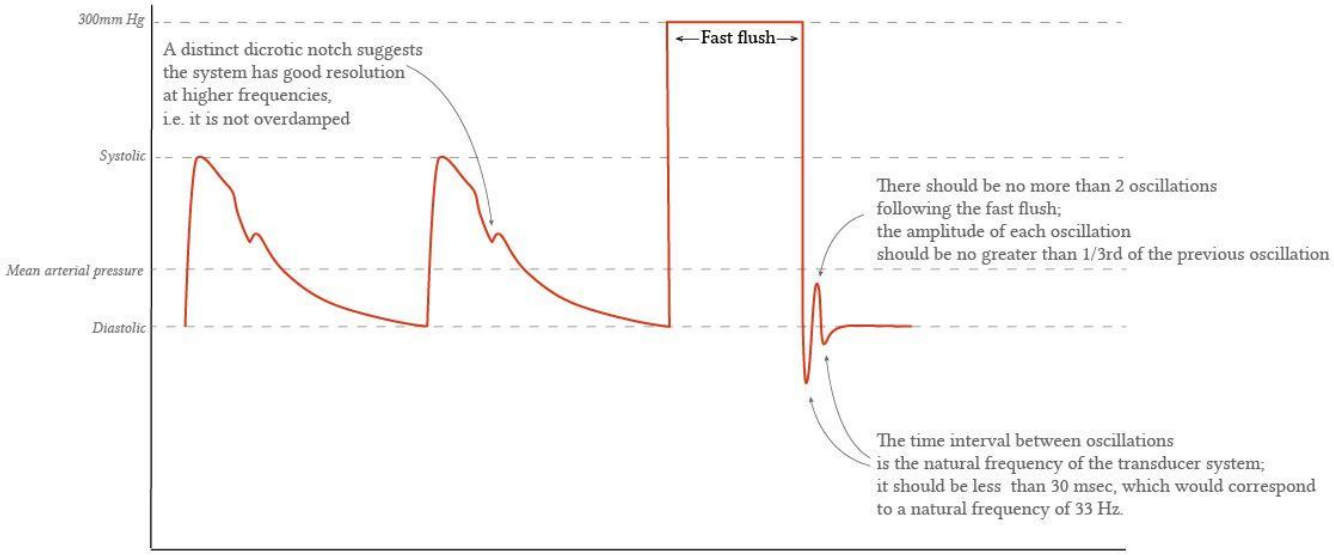
Yentis SM, Hirsch NP, Smith GB. 2003 Anaesthesia and Intensive Care A-Z 3rd edition p44 Butterworth Heineman

APPENDIX 1.

Arterial line dynamic response testing

The square wave test

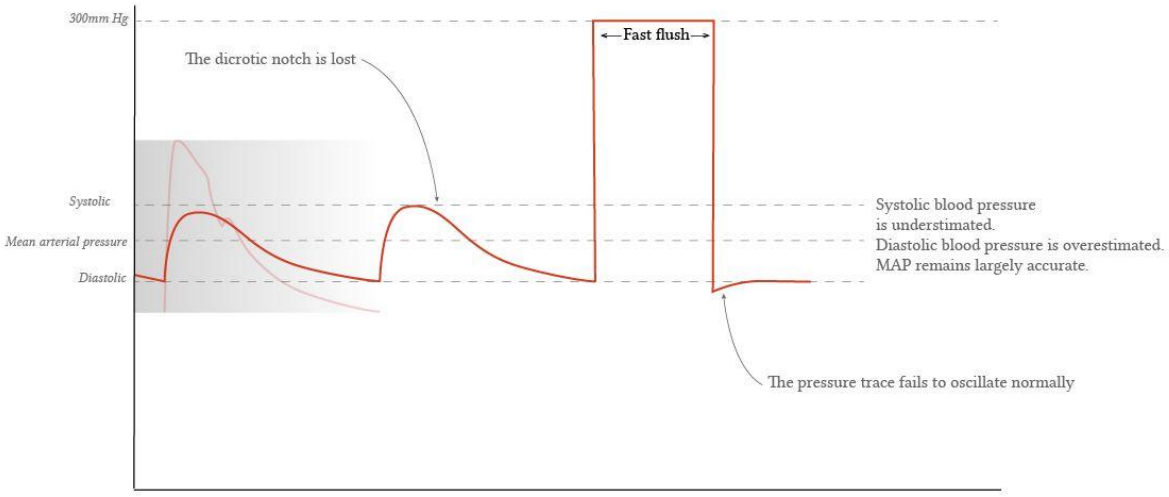
When you squeeze the fast flush valve, you let the transducer taste some of the 300mmHg in the pressurized saline bag. This produces a waveform that rises sharply, plateaus, and drops off sharply when the flush valve is released again.



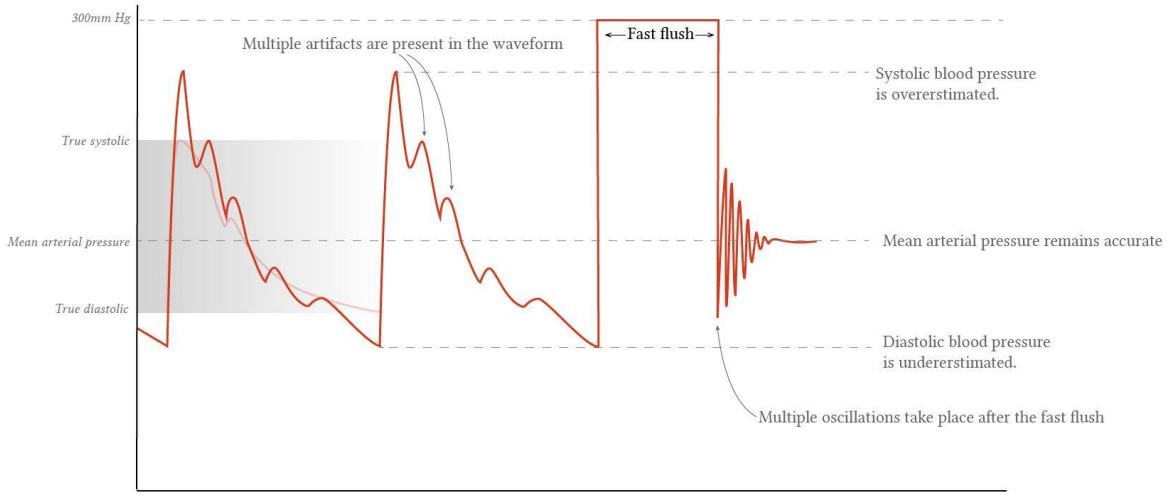
After the fast flush has ended the transducer system returns to baseline, dings so as a harmonic oscillator, "bouncing" a couple of times before coming to rest. This "bounce" can be used to determine the resonance characteristics of the system. The accurate, responsive, adequately damped arterial line waveform will have the following features:

- **The time between oscillations will be short.** This is the natural frequency of the system, and it should be less than 20-30 msec in order to resolve the details in the arterial pulse waveform.
- **There should be at least one "bounce" oscillation.** If the system does not oscillate, there is too much damping.
- **There should be no more than two oscillations;** system which oscillates too much is underdamped.
- **There should be a distinct dicrotic notch.** The dicrotic notch is resolved from high-frequency waveforms, which are usually of low amplitude and therefore more susceptible to damping. If the arterial line is progressively becoming more and more damped, the dicrotic notch is the first feature to disappear

The over-damped arterial line waveform



The under-damped arterial line waveform



The use of this guideline is subject to professional judgement and accountability. This guideline has been prepared carefully and in good faith for use within the Departments of Critical Care at Royal Sussex County Hospital and Princess Royal Hospital. The decision to implement this guideline is at the discretion of the on-call critical care consultant in conjunction with appropriate critical care medical / nursing staff.