Guideline Title: Arterial lines monitoring and management.

Summary: This guideline has been created so staff in ICU will be able to practice within its framework. It provides a guideline for the competent management of arterial lines including insertion, monitoring of invasive blood pressure, care and maintenance, and blood sample collection via the arterial pressure device.

Approved by: ICU Medical Director

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Replaces Existing Guideline: Replacing 1995 Arterial Line Policy

Previous Review Dates: 2011

Background Information:
Critically ill patients require arterial lines to monitor blood pressure (BP) trends, titrate drug therapies and obtain blood samples for arterial blood gases and laboratory studies. To ensure that a patient receives optimal treatment, it is crucial that staffs are aware of factors that affect the safety and accuracy of arterial monitoring. In addition, to ensure that the opportunity for blood stream infection is minimized standard precautions must be followed. Arterial pressure monitoring allows for continuous monitoring of systemic arterial blood pressure and provides vascular access for obtaining blood samples. It is indicated in patients receiving vasoactive infusions or those with fluctuating, unstable blood pressures. An arterial catheter is inserted into the radial, brachial, femoral, or dorsalis pedis artery. The radial artery is the preferred site because of accessibility. The catheter is attached to a fluid-filled pressure transducer system incorporating a flush system, which continuously infuses a 0.9% sodium chlorides solution under pressure to maintain patency of the catheter. An attached transducer senses arterial pressure and converts the pressure signal to a waveform on the bedside monitor. The waveform reflects pressure generated by the left ventricle during systole. The monitor also displays numerical pressure values.

Related Policies/documents
- LH_ICU_Arterial_Blood_Gas_Interpretation
- LH_ICU_Femstop_femoral_compression_device
- Liverpool Hospital ICU Arterial catheterization education package

1. Introduction:
The risk addressed by this policy:

- Safe and competent management of arterial lines including insertion, care and maintenance, and blood sample collection via the arterial pressure device in the ICU.
- Accurate monitoring of invasive blood pressure.
The Aims / Expected Outcome of this policy:

- To ensure that patients receive optimal management when they require or have an arterial blood pressure device in situ.
- That staff are aware of factors that affect the safety and accuracy of arterial monitoring and management of the patient with an arterial line in situ.
- To ensure that the opportunity for blood stream infection(s) is minimised.

2. Policy Statement:

- All care provided within Liverpool Hospital will be in accordance with infection prevention/control, manual handling and minimization and management of aggression guidelines.
- Only a medical officer or accredited staff performs insertion of the arterial catheter.
- The procedure of insertion is performed under strict aseptic technique.
- Pressure bag needs to be inflated to 300mmHg which infuses 3-5ml/hr.
- Flush bags of 0.9% sodium chloride are changed every 24 hrs or prn.
- Fast flush solutions after opening the system for blood sampling and/or zeroing to eliminate air bubbles and clear the line of residual blood. Air bubbles may lead to wrong pressure reading.
- Ensure the line and blood sampling port is free of blood at all times and closed to air with an arterial line cup.
- For radial and brachial arterial lines keep the arm in extended position for accuracy and patency of the line.
- Keep the arterial site clearly visible at all times. eg. On top of sheets. Use a clear type dressing over the arterial line exit site for clear view of the site at all times and to prevent unnoticed adverse events such as haemorrhage or disconnection and signs of infection.
- Position the transducer so that it is level with the heart or phlebostatic axis (4th intercostal space mid axillary line).
- Secure arterial line appropriately as per guidelines/ recommendations.
- Set appropriate scale and alarm parameters every shift and as appropriate.
- Set appropriate arterial blood pressure label on the patient monitor.
- Alarms to remain on at all times, with appropriately set limits.
- Check for signs of infection (redness, swelling, pain and discharge) and document on your shift. Inform Medical Officer if applicable
- Arterial line must be labeled.
- Only dedicated arterial bungs or arterial cannula caps are to be used after replacing the cap that comes in the arterial or transducer set.
- Re-zero the transducer once per shift or as required such as after disconnection from the monitor and/or transducer cable, after re dressing the arterial site, after accessing the arterial line for blood sample, after troubleshooting the line, etc.
- Ensure that there is a non-invasive blood pressure cuff and module in the bed area available if necessary.
- When measuring non-invasive blood pressure (NIBP) use alternate arm to invasive arterial cannulation.
- Do not inject any medication or other substances via the arterial line. The only purpose of an arterial line if for close blood pressure monitoring and blood sampling.

3. Principles / Guidelines

Indications for Arterial Lines:

Patients may require an arterial line for:

- Monitoring continuous blood pressure especially in patients with haemodynamic instability.
- When vasoactive medications are needed and the responses to such medications require continuous blood pressure monitoring.
- For patients who require frequent blood sampling.
3.1 Insertion of Arterial Lines:

Equipment:
- Clean and dry dressing trolley
- Sterile drape
- Minor procedure tray or dressing pack
- Extra gauze if necessary
- Arterial cannula or arterial insertion set as appropriate
- 2% Chlorhexidine in 70% Alcohol solution
- A separate tray for sodium chloride. Quantity as required
- A kidney tray for keeping sharps for disposal (optional)
- Two 25g needle + two 5mL syringe
- One drawing up needle for Lignocaine as required
- 1x transparent occlusive dressing (e.g. iv 3000)
- Fenestrated drape
- Sterile gown + sterile gloves
- Transducer, pressure bag and 500ml of sterile 0.9% sodium chloride
- Pressure cable attached to Phillip monitor
- 1% Lignocaine (optional)
- 3.0 silk + needle (optional)

Preparation of Patient:
- Explain procedure to patient
- Verbal consent should be obtained by the medical officer or accredited staff performing the procedure.
- The person performing the procedure should do the Allen's test to ensure adequate distal blood flow if a radial artery is being cannulated.
- Position pt in bed as comfortable as possible with the area to be used exposed. (NB if a radial artery is to be used a rolled towel may be used to hyperextend wrist to allow easier visualization of landmarks).

Performing a modified Allen’s Test
- Instruct the patient to clench his/her fist, or if the patient is unable, you may close the hand tightly.
- Using your fingers, apply occlusive pressure to both the ulnar and radial arteries. This manoeuvre obstructs blood flow to the hand.
- While applying occlusive pressure to both the arteries, have the patient relax his/her hand. Blanching of the palm and fingers should occur. If it does not, you have not completely occluded the arteries with your fingers.
- Release the occlusive pressure on the ulnar artery. You should notice a flushing of the hand within 5 to 15 seconds. This denotes that the ulnar artery if patent and has good blood flow. This normal flushing of the hand is considered to be a positive modified Allen’s test. A negative modified Allen’s test is one in which the hand does not flush within the specified time period. This indicates that ulnar circulation is inadequate or nonexistence. The radial artery supplying arterial blood to that hand should not be punctured.

University of Connecticut. (2006). Acid base online tutorial
Documentation:
- The person who performed procedure (proceduralist) needs to document in the clinical health records.
- Nursing staff need to document on management/care plan, date of insertion site, when next dressing + line change due + date for removal.
- The arterial line can remain insitu for up to 7 days, or longer in special situations as deemed necessary by the clinician, unless signs of infection are evident, not working efficiently, unexplained pyrexia or if the arterial line is no longer required.
- The site must be reviewed regularly and findings must be documented in the clinical health records.
- Suturing: It may be necessary to use a skin suture for the arterial line in certain situations such as patients with difficult access, diaphoretic patients or when there is difficulty in securing with transparent dressing alone.

3.2 Transducer Set Up
Rationale:
- The arterial catheter is connected to the fluid filled tubing of the monitoring system.
- The transducer creates the link between the fluid filled tubing system and the electronic system converting a mechanical signal into a waveform on the monitor.
- The transducer system must be set up correctly to ensure accuracy of the monitoring system.

Procedure:
- Insert giving set attached to the transducer or transducer set, into 0.9% sodium chloride bag, keeping end sterile, ready to pass to the staff performing the procedure.
- Ensure all roller clamps are open
- Place the sodium chloride into the pressure bag and inflate to 300 mmHg.
- Prime line by squeezing fast flush device.
- Ensure that all air bubbles are removed from the system and that all parts are primed with fluid. Air can cause damping of the system and inaccuracy of monitoring.
- When the line is inserted and the proceduralist is ready connect to the cannula.
- Connect transducer to the Philip cable and watch for the arterial blood pressure trace on the monitor.
- Zero + calibrate system.

3.3 Arterial Pressure Monitoring

- The arterial pressure wave corresponds with the cardiac cycle.
- Systole begins with opening of aortic valve and rapid ejection of blood into the aorta. This is the upswing on the arterial waveform followed by a downward turn.
- A notch—called the dicrotic notch—is visible on downward stroke which represents closure of the aortic valve signifying the beginning of diastole.
- The remainder of the downward stroke represents diastolic run off of blood flow into the arterial tree.
- The QRS complex of ECG trace comes first and the arterial waveform follows.

Arterial Waveforms

![Normal arterial blood pressure wave](image)


Picture adapted by Paula Sanchez, RN, Liverpool ICU, 2011.

Comparing normal and abnormal arterial blood pressure waves

![Comparing normal and abnormal arterial blood pressure waves](image)


**Damping.** Is important to have appropriate amount of damping in the system. Inadequate damping will result in excessive resonance in the system and an overestimate of systolic pressure and an underestimate of diastolic pressure. The opposite occurs with overdamping. In both cases the mean arterial pressure is the most accurate. An underdamped trace is often characterized by a high initial spike in the waveform.
Assessing dynamic response
- If you suspect the values displayed on the bedside monitor are inaccurate or if the tracings are not clear one can verify the dynamic response (accuracy) of the pressure system by performing the Fast Flush test or Square Wave test. This can only be undertaken if the flush device has a restrictor that opens and closes rapidly (a pull or snap tab in situ).
- Squeeze the pull or snap tab on the flush device rapidly then quickly release it
- The monitor should show a waveform that rises suddenly and sharply, tops off, then declines sharply. As you release, one or two oscillations appear above and below the baseline after release, indicating **optimal dynamic response**
- The dicrotic notch should be clear, as the picture below.

![Waveform Image]

- **Note:** flicking the pressure line can cause enough oscillation for a square wave test but this method isn’t as accurate.

Overdamped trace
- The tracing will have less than 1 1/2 oscillations below the baseline. The dicrotic notch won’t be clear or sharp. Over dampening results in false-low systolic pressure but usually accurate diastolic pressure. The MAP is usually accurate. This may be due to clot or fibrin build-up in the catheter tip.

![Waveform Image]
Underdamped tracing

- “Ringing” or oscillations below and above the baseline. This leads to false-high systolic pressures and false-low diastolic pressures. Peak systolic tracings may show more than one sharp upstroke and diastolic points are hard to differentiate. The MAP is usually accurate.

3.4 Arterial Transducer Leveling and Zeroing (Calibrating the system)

Rationale:
- To ensure consistency and accuracy of the arterial blood pressure monitoring the transducer must be positioned and calibrated regularly to an anatomically consistent site. This site is called the **phlebostatic axis**.

Leveling:
- The phlebostatic axis is the anatomical reference point on the chest that is used as baseline for consistent transducer site placement. This point represents the position of the atria and therefore reflects central blood pressure.
- The site of the phlebostatic axis is at the intersection of the fourth intercostal space and mid axillary line.

Schema of the phlebostatic level

*Arterial catheter setup in adult. Schema of the phlebostatic level.* As the patient moves from the flat to the upright position, the phlebostatic level rotates on the axis and remains horizontal. The reference stopcock of the transducer must be levelled to the phlebostatic axis. Moving from supine to a sitting position changes the reference level and could lead to erroneous pressure measurements.

Zeroing
- Zeroing is the method of calibrating the monitoring system so that the effects of atmospheric and hydrostatic pressure are eliminated.
- Zeroing must be carried out once per shift or as required such as after disconnection from the monitor and/or transducer cable, after re-dressing the arterial site, after accessing the arterial line for blood sample, after troubleshooting the line, etc.

Procedure for zeroing
- Position patient on their back
- Patient may be positioned with the head of the bed elevated between 0-60°
- Flush the system
- Level transducer to phlebostatic axis (see figure).
- Turn stop-cock on transducer so that it is off to the patient.
- Remove cap
- Press zero on the module
- Ensure that zero appears on screen replace cap and turn stop-cock so that it is open to monitoring and patient.
- NB: If patient is positioned on their side the reference point will be different. It is difficult to identify true phlebostatic axis. There may be a discrepancy in readings. If there is a great variation when positioned on their sides. The patient should be placed onto their back and a true reading obtained.

3.5 Blood Sampling
- May be attended by staffs who have undertaken appropriate education or accreditation.
- Contraindicated when is difficult to ensure good blood flow from the arterial line due to positional cannula, thrombosed artery or low arterial pressure.
- Arterial spasm may occur if the blood is withdrawn at a faster rate than the artery can supply.
- Minimise accessing the line.

From arterial line using vacutainer
This is the preferred method of collecting blood from an arterial line.

Equipment
- Universal precautions equipment
- Blue sheet
- Alcohol wipe
- 3 or 5ml syringe as required
- Vacutainer barrel
- Luer adapter
- Gauze
- Blood tubes as required
- Pathology Bag

Method
- Observe universal precautions.
- Remove short cap from luer adapter and carefully screw into a vacutainer barrel.
- Temporarily silence monitor alarms.
- Open the gauze, and use the inside of the packet as a sterile field.
- Turn arterial line tap off to the patient.
- Unscrew the arterial line cap and place on inside of gauze packet.
- Swab the port with the alcohol wipe.
- Remove the long cap from the luer adapter and connect to the arterial line port.
- Push a white top tube into the barrel until the rubber stopper is punctured.
- Turn the tap off to the flush bag; blood should begin to fill the tube withdrawing blood (white tube holds about 5mls) to clear the dead space in the line as required, more if dead space is bigger.
- Discard the white top tube.
- Fill relevant tubes as outlined above in the following order:
  - blue top
  - white top
  - green top
  - purple top
  - pink top
  - grey top
- Turn the tap off between arterial line transducer and the patient between tubes
- Once removed, gently invert the tube 8-10 times whilst the replacement tube is filling, to mix additives with the blood.
- An arterial blood gas may be collected if indicated.
- Turn the tap off to the open port and remove the vacutainer barrel.
- Flush the line clear of blood using the arterial flush device.
- Turn the tap off to the patient and flush blood out of the port onto a folded gauze square.
- Turn the tap off to the open port and check that the arterial trace returns on the monitor. Re-zero the arterial line to the monitor if required.
- Reapply or replace the arterial cap to the port as appropriate.
- Place the labelled tubes in the pathology bag and send with a signed request form to pathology.
- The barrel is not disposable unless contaminated.

From arterial line using a syringe

**Equipment**
- Universal precaution equipment
- Blue Sheet
- Alcohol wipe
- 3 or 5ml syringe as required
- 10ml or 20ml syringe
- Gauze
- Blood tubes as required
- Pathology bag

**Method**
- Observe universal precautions.
- Temporarily silence monitor alarms.
- Open the gauze and use the inside of the packet as a sterile field.
- Remove cap from three way tap and place inside of gauze packet.
- Unscrew the arterial and place on the inside of gauze packet.
- Swab the port with the alcohol wipe.
- Connect the 3 or 5ml syringe as required.
- Turn the tap off to the flush bag and withdraw 3mls of blood to clear dead space in the line as required, more if dead space is bigger.
- Turn the tap off to the patient and remove the syringe.
- Connect the 10 or 20ml syringe, depending on the volume of blood required.
- Turn the tap off to the flush bag and gently withdraw the required amount of blood.
- Turn the tap off to the open port and remove the syringe.
- Flush the line clear of blood using the arterial flush device.
- Turn the tap off to the patient and flush blood out of the port onto a folded gauze square.
- Turn the tap off to the open port and check that the arterial trace returns on the monitor. Re zero the arterial line to the monitor if required.
- Reapply or replace the arterial cap to the port as appropriate.
- Place tubes in the pathology bag and send with a signed request form to pathology.
• Reapply or replace the arterial cap to the port as appropriate.
• Distribute the required amount of blood into each of the blood tubes. This is to be done by removing the coloured tops of the tubes (without spilling the additive inside the tube).
• **DO NOT** puncture the rubber stopper on the blood tubes with a needle.
• An arterial blood gas may be collected if indicated.
• When filled, replace the coloured top and gently invert the tube 8 to 10 times to mix the additives with the blood.
• Place tubes in the pathology bag and send with a signed request form to Pathology.

3.6 Dressing the Arterial Line

**Rationale:**
Infection at the arterial catheter site will be minimised by the following:
- Dressings should be left intact on the arterial line.
- Dressings should be attended when required, if there is a problem with kinking of line, leaking around site, dirty or if the dressing is coming off.
- **Do not use** any non-transparent dressing so the exit site is well in view.
- With hand board or backslab, make sure that the board and the patient’s hand are washed and kept clean and dry at all times.

**Equipment**
- Dressing Pack
- Sterile Gloves
- Transparent occlusive dressing
- 2% Chlorhexidine in 70% Alcohol solution
- Adherent solution such as skin barrier swab or op-site spray optional
- Gown and goggles

**Method**
- Observe universal precautions.
- Assemble equipment on dressing trolley.
- Wash hands.
- Don gloves.
- Remove old dressing carefully.
- Wash hands and don sterile gloves.
- Cleanse area with Sodium Chloride (if visibly soiled or crusting is present).
- Dry site with gauze.
- Apply 2% chlorhexidine in 70% alcohol to insertion site.
- Allow to dry to air.
- Apply adherent solution to assist adhesion of the transparent dressing if required.
- Apply transparent dressing so that insertion point of cannula is in middle of the dressing.
- Apply back slab to radial arterial line.

**NB.** Transducer only needs to be changed if considered to be giving faulty readings or if not compatible to Philip equipment (used at Liverpool ICU).

3.7 Removal of Arterial Line

**Rationale:**
The arterial line should be removed if:
- The arterial line is no longer required for close blood pressure monitoring and/or frequent blood sampling.
- There are any signs of infection, phlebitis or no longer functioning well.
- When the patient has signs of sepsis and the ICU Team has decided to replace all lines.
Equipment
- Dressing Pack
- Sterile gauze
- Tape
- Gloves
- Occlusive dressing as necessary
- 2% Chlorhexidine in 70% Alcohol solution
- Stitch cutter if arterial line has been sutured
- Femstop if femoral artery line being removed and there is potential for bleeding post removal.

Method:
- Adhere to universal precautions.
- Ensure that a non-invasive blood pressure (NIBP) cuff is attached to the patient if monitoring is still required.
- Prepare the sterile field using the dressing pack adhering to aseptic technique adding all necessary equipment (stitch cutter, cleaning solution, extra gauze, new dressing if necessary, etc).
- Suspend or turn the ABP alarm off.
- Deflate the pressure bag and clamp the IV tubing.
- Remove all dressing.
- Cut suture if applicable
- Remove the cannula while pressing firmly over the insertion site with gauze for approximately 5 minutes. If femoral line press firmly for 10 minutes.
- Consider the use of a Femstop when removing a femoral arterial line (See the Clinical use of the Femstop II post removal of femoral arterial/venous sheath(s) guideline).
- Consider the patient's coagulation status prior to removal of the line.
- Observe for further bleeding then apply dressing.
- Continue to observe site for potential bleeding.

3.8 Troubleshooting

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>POSSIBLE CAUSE(S)</th>
<th>SOLUTION/MANAGEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulty with zeroing</td>
<td>Not connected properly. Line not primed appropriately through the transducer. Faulty transducer or pressure cable. Number display not set up/selected on the monitor for ABP. System not open to air</td>
<td>Check all equipment and connections between pt and monitor. Ensure all roller clamps are open. Check system for air bubbles and blood clots. Recalibrate. Replace transducer, cable and/or module. Replace arterial line (last resource).</td>
</tr>
<tr>
<td>Unable to aspirate cannula</td>
<td>Kinked or blocked line and/or cannula.</td>
<td>Check line for kinks. Apply traction to cannula. Gently try to flush. Replace arterial line.</td>
</tr>
<tr>
<td>Falsely high or low readings</td>
<td>Incorrect placement or transducer, either too high or too low in relation to the patient’s phlebostatic axis.</td>
<td>Perform square waveform check. Check position of transducer. Re-zero. Re position patient’s arm.</td>
</tr>
<tr>
<td>Uncalibrated system. Kinked or blocked cannula.</td>
<td>Apply back slab to maintain extension on entry point. Remove kink. Unclamp rolled clamp(s) in line. Remove air bubbles/ blood clots. Check adequate amount of fluid in the flush bag. Ensure pressure bag is inflated to 300mmHg. Re dress if necessary.</td>
<td></td>
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</tr>
<tr>
<td>Haemorrhage</td>
<td>Disconnection.</td>
<td>To prevent: Keep limb visible at all times. Ensure alarm is on so that any accidental disconnection can be dealt with quickly. Ensure that arm is immobile with arm board. Ensure all connections are tight. If hemorrhage: Apply pressure to limb. Assess leak. If hemorrhage persists notify MO.</td>
</tr>
<tr>
<td>Infection</td>
<td>Presence of pathogen in the arterial line/site.</td>
<td>To prevent: Assess area regularly for any signs of infection document. Avoid interrupting circuit as much as possible. Use universal precautions when dealing with arterial line. Change dressing when necessary to keep dry and clean. If infection: Remove arterial line. If tip is sent for culture it should be accompanied by blood culture.</td>
</tr>
<tr>
<td>Blockage/Clotting/Air emboli</td>
<td>Kinked line. Disconnection or loose connection. Not enough pressure on the pressure bag. Insufficient fluid in the 0.9% Sodium Chloride on the pressure bag. Line not flushed when there is the presence of blood in the line. Line not primed properly.</td>
<td>To prevent: Keep pressure bag inflated to ensure a pressure of 300mmHg (3-5ml/h). Ensure all connections are secure. Maintain line and blood collection port free of blood at all times. Use fast flush device to clear line to prevent clot formation. Never flush a clot or air embolism into the patient. If clot/air embolism: Attempt to aspirate blood/air to remove clot.</td>
</tr>
<tr>
<td>Interruption to peripheral circulation</td>
<td>Distal ischaemia. Arterial thrombosis embolism. Dressing too tight.</td>
<td>To prevent: Regularly check distal vascular observations and document. Keep dressing and board straps not too tight.</td>
</tr>
</tbody>
</table>
4. Performance Measures
All incidents are documented using the hospital electronic reporting system: IIMS and managed appropriately by the NUM and staff as directed.

5. References / Links

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