Ultrasound (US) assistance for Central Venous Catheterization (CVC) and Peripherally Inserted Central Catheters (PICC)

Education - Training plan for Critical Care Nurses

Pre-reading

The Canberra Hospital – Intensive Care – Dr Marta Kot & Dr Bronwyn Avard
Objectives

- Comprehensive pre-reading for assisting Central Vascular Catheterization (CVC) and Peripherally Inserted Central Catheters (PICC) under real time ultrasound (US) guidance:
  1. Acquire theoretical knowledge of surface landmarks and ultrasound anatomy.
  2. Recognise indications, contraindications and complications.
  3. Learn to assist with ultrasound to perform the procedure following standards, including the preparation of patient, operator, assistant, equipment and materials; pre scanning; sterile and Seldinger techniques.
  4. Provide the knowledge base to effectively participate in tutorials and hands-on sessions.
CENTRAL VENOUS CATHETERIZATION

Pre-reading topics

*(Total estimated time required: 50 – 65 min)*

1. **Indications, Contraindications, Potential complications (4 - 5 min)**
2. **Preparation (4 - 5 min)**
3. **Pre scanning (15 – 20 min)**
4. **Sterile technique (2 – 3 min)**
5. **Procedural technique: Steps (20 – 25 min)**
6. **Confirmation of satisfactory completion (2 – 3 min)**
7. **Documentation (2 – 3 min)**
8. **Additional reading**
9. **Assessment**
CENTRAL VENOUS CATHETERIZATION

Pre-reading

Index (click hyperlink)

1. Indications, Contraindications, Potential complications
2. Preparation
3. Pre scanning
4. Sterile technique
5. Procedural technique: Steps
   - Central Venous Catheter
   - Peripherally Inserted Central Catheter
6. Confirmation of satisfactory completion
7. Documentation
8. Additional reading
9. Assessment

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1 \ Indications

Contraindications

Potential complications
Indications:

- **Measurement:**
  - Central venous pressure, ScvO2

- **Access for:**
  - Enable delivery of caustic or irritant medications
  - Haemodialysis;
  - Pulmonary artery catheters;
  - Transvenous pacing;
  - Transjugular intrahepatic portal shunt, transjugular hepatic biopsy;
  - Endomyocardial biopsy;

- Active endovascular cooling devices
Contraindications:

- Skin or subcutaneous infection overlying the target vein (choose alternate site)
- Thrombosis of the target vein (choose alternate site)

Relative:
- Site – specific
- Depends on the clinical context and operator experience
- Severe coagulopathy
- Distorted anatomy
- Operator inexperience
- Lack of supervision

More experienced operator should be consulted – to make a judgement according to clinical context (alternate sites/lines)
Potential complications: Infections

**Mechanisms:**
- Local insertion site
- Hub colonization
- Intraluminal - haematogenous seeding

**Recommendations to reduce central line infections:**
- Hand hygiene
- Adherence to maximal barrier precautions
- Chlorhexidine/alcohol skin antisepsis
- Selection of optimal catheter site
- Daily review of the necessity of the catheter for prompt removal when it is not longer needed
- Removal as not longer needed
- Reduce number of attempts → US guidance

**Not routinely recommended:**
- Scheduled changing → increases mechanical and infectious complications rate over guide wire or moving to new site
- Antibiotic ointments → promotes antibiotic resistant bacteria and fungal colonization
Potential complications: Mechanical

- Arterial puncture
- Haematoma
- Pseudoaneurysm
- Pneumothorax
- Haemothorax
- Arrhythmia
- Improper location of catheter
  - Accessory vein, upper vascular system
Potential complications: Thrombotic

- Lower risk = Subclavian vein
- Higher risk = PICC (Brachial)

- Be aware of potential of thromboses in target vein, e.g. prior CVCs
Preparation

Patient
Equipment
Materials
Assistant
Preparation: Patient

- Consent
  - Inform patient or substitute for consenting if appropriate
    - Reason – indication
    - Technique
    - Potential complications
  - Consent is usually not required in ICU

- Coagulation
  - Check risk of bleeding (clinically, laboratory, antiplatelet agents)
Preparation: Patient

Positioning:

- Head tilt down (Trendelenburg position 5 – 15 degrees)
  - To increase vein size
  - To prevent air embolism
  - IF not contraindicated e.g. acute intracranial pathology; vomiting

- Head rotated \( \leq 30 \) degrees
  - Avoid excessive rotation that causes vein collapse and anatomical distortion
  - Do not rotate if patient has spinal precautions (collar, sand-bag)

- Adjust height of the bed for operator comfort
Preparation: Equipment and materials

- Monitors:
  - Minimal: ECG, SpO2
  - Other monitors:
    - Specific to patient needs and management
  - Pressure transducer
    - If CVC to be used in emergency without CxR confirmation
Preparation: Equipment and materials

- **CLAB checklist** (see documentation)

- **Sterile field**
  - Gown, gloves, mask/eyewear, hat
  - Strict sterile technique – large drapes & procedure pack
  - Chlorhexidine/alcohol

- **Prepacked catheter insertion kits:**
  - Syringes (usually 1x10mL, 2x5mL), needles (usually 23/25 G plus blunt drawing needle)
  - Gauze
  - Catheter
    - **CVC** → Appropriate lumen size to deliver the required medication or treatment (i.e.: larger bore for dialysis and rapid fluid resuscitation)
    - **PICC** → Single or double lumen
    - Appropriate length to reach the junction of vena cava and right atrium (measured against patient’s anatomy)
    - Catheter flushed
  - Saline & lignocaine

- **Securing system – sutures; ‘stat-lock’**

- **Dressing**
Preparation: The Assistant

- Monitoring the patient
- Allocated role
- Trained

Assistance required:
- Handling materials
- Ultrasound:
  - Sterile sheath for probe cover
  - US settings adjustment
  - Scanning neck during PICC insertions
Pre scanning

Rationale
Evidence
Techniques
Real US guidance for CVC – PICC insertion

Rationale

- Landmark methods:
  - Experienced operators can achieve relatively high success rates
  - Failure rates in the literature have been reported to be as high as 35% without ultrasound assistance
  - Anatomical relationships are variable
  - Multiple catheterizations and comorbidities increase the risk of thrombosis.
Real US guidance for CVC – PICC insertion

Rationale

- Ultrasound has particular advantages over other imaging modalities such as computed tomography and fluoroscopy:
  - Real-time visualization, rapid diagnosis of anatomy and patency
  - Portability permitting bedside procedures
  - Minimally invasive
  - Reduced exposure to radiation and nephrotoxic contrast agents
Real US guidance for CVC – PICC insertion

Rationale

- Image – guided procedures:
  - Expedite procedure times
  - Increase accuracy, safety, and efficacy of many procedures commonly performed within intensive care units
  - Decreases the need of reinsertion, recognizing malposition before removing the sterile field
Real US guidance for CVC insertion
Evidence

- **The National Institute for Clinical Excellence UK – 2002 - 30** RCTs pool analysis:
  - Ultrasound has statistically significant beneficial outcome effects over the landmark method, which is strongest for Internal Jugular veins and paediatric population.
  - The more a machine is used for cost-effective procedures, the better the cost-effectiveness result for ultrasound in the central venous access context.
  - In emergency line insertions, landmark techniques may still be appropriate, so US training must allow operators to remain skilled in landmark methods.
  - Each pass of a needle during the venepuncture is associated with risk of complications.

- **Agency for Healthcare Research and Quality – US**
  - Recommended the use of ultrasound for the placement of central venous catheters (CVCs) as one of their 11 practices to improve patient care – 2001
Real US guidance for CVC – PICC insertion

Advantages

- Visualisation of the precise target location:
  - Clarifies relative position of the needle, vein and surrounding structures
  - Assess variant anatomy and patency of the target vein
- Identify alternate routes for access
- Visualisation of needle progression
- Lower technical failure (overall and first attempt)
  - Reduced puncture attempts
  - Improved success rates
  - Reduction in complications
- Faster access – lower cannulation time
- Control of catheter location
  - Identify malposition before removing the sterile field (i.e.: PICC line ascending to neck vessels)
Real US guidance for CVC – PICC insertion

Disadvantages

- Time-consuming learning process
- Initial time demand to power and set up the device and to cover the probe with a sterile sheath
- Potential to deskilling the landmark method required in emergency situations
- Real expense of the ultrasound devices
- Risk of litigation after CVC insertion for not using ultrasound guidance
- Experienced operators reluctantly using ultrasound to guide real-time needle insertion
- Limited for Subclavian access (requires pencil point probe)
Real US guidance for CVC – PICC insertion
Limitations

- Use of US does not completely eliminate other potentially fatal complications of venous access (such as air embolus, pneumothorax, mediastinal venous laceration with large dilators or sheaths, cardiac tamponade from atrial wall erosion, infection and sepsis)
- Equipment and transducer availability: use linear array - high frequency probe (6-10 MHz)
- Sterile barrier: required sterile probe cover sheath
- Education and training: limited animal, cadaveric or phantom models
- Time to cannulation and operator experience: the learning curve is short and steep
Pre-scanning
Prior to sterile field

- Objectives:
  - Select the most appropriate site of insertion
    - Assess anatomy
    - Assess variability during positioning change
    - Assess vessel patency
  - Adjust US settings
    - Not always available assistant with US skills
      - Critical Care Nurses should be trained for focused ultrasound assessments during vascular access insertion
  - Position US machine:
    - Adequate for operator
      - Real time US guidance
      - Facing the operator

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### Scanning

Identify vessels and structures

<table>
<thead>
<tr>
<th>VEIN</th>
<th>ARTERY</th>
<th>LYMPH NODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>More variable shape</td>
<td>More rounded shape</td>
<td>Different shapes - sizes</td>
</tr>
<tr>
<td>Thinner walls</td>
<td>Thicker walls</td>
<td>Be aware of “oblique” insonation</td>
</tr>
<tr>
<td>Thrombosed veins can have thicker walls</td>
<td>Young, healthy and small arteries have thinner walls</td>
<td></td>
</tr>
<tr>
<td>Compressible if patent</td>
<td>Very less compressible</td>
<td>Non compressible</td>
</tr>
<tr>
<td>Be aware of “falling” on one side of the vessel if long axes interrogation</td>
<td>Young healthy and small arteries , and hypovolaemic patients have compressible arteries</td>
<td></td>
</tr>
<tr>
<td>Non pulsatile</td>
<td>Pulsatile</td>
<td>No Doppler signal</td>
</tr>
<tr>
<td>Pulsatile if TR</td>
<td>Reduced pulsatility if shock, low CO state, bradycardia</td>
<td></td>
</tr>
<tr>
<td>Looks pulsatile if transmitted from artery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scanning techniques</td>
<td>Transversely (short axis view)</td>
<td>Longitudinally (long axis view)</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Vessels view</td>
<td>Simultaneously artery and vein</td>
<td>Not simultaneously seen unless one underneath the other.</td>
</tr>
<tr>
<td>Scanning to identify best position</td>
<td>Proximally - distally</td>
<td>Medially - laterally</td>
</tr>
<tr>
<td>Needle seen</td>
<td>Point</td>
<td>Full length if same US plane Partially depending on US beam plane</td>
</tr>
<tr>
<td>Needle identified</td>
<td>Tissue movement – anterior wall depression Posterior reverberation artefact</td>
<td>Partially or tissue movement Posterior reverberation artefact</td>
</tr>
<tr>
<td>Learning curve</td>
<td>Shorter</td>
<td>Longer</td>
</tr>
<tr>
<td>Advantages</td>
<td>Compression for differentiating artery – vein – lymph node Easier for collapsed vessels</td>
<td>Better seen needle advancing → Less likely posterior wall penetration</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>Needle not seen → Risk of posterior wall penetration</td>
<td>Risk of displacement lateral to vessel Not simultaneously seen artery and vein More difficult if collapsed vessel</td>
</tr>
</tbody>
</table>

*This topic will be fully explained during the tutorial and hands-on sessions*
Scanning planes


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Select the most appropriate site of insertion

Consider:
- Overlapping vessels
- Patency - Compressibility
Sterile technique
Sterile technique:

- **Hand hygiene:** before and after
- **Sterilise** the area
  - Chlorhexidine
    - Circular motion from center to edge of field ≥ 2 times
    - Larger area than expected
    - Leave to dry ≥ 2 minutes
- **Maintain universal contact barrier precautions**
  - Surgical hat, mask, eye protection
  - Sterile field:
    - Gown, gloves
    - Drapes to cover patient ‘head to toe’
Procedural technique

Steps
Procedural technique: Steps

- **Select insertion site:**
  - Patient’s individual situation and landmarks
  - Use of the vascular access
  - Risk of complications (infection, mechanical, bleeding)
  - Pre-scanning

- **Surface anatomy and landmark technique:**
  - Site specific
    - Particularly for Subclavian site
      - More difficult ultrasound scanning (bone – lung)
      - Required specific – pencil point probe (not commonly available)
Procedural technique: Landmark

- Subclavian vein
- Jugular vein
- Femoral vein
- Brachial vein (PICC)
Anatomy

diagram of the upper body with labels:
- thoracic duct
- parotid gland
- left brachiocephalic
- carotid artery
- external jugular vein
- right brachiocephalic
- internal jugular
- vagus nerve
- pulmonary apex
- phrenic nerve
- subclavian artery and vein
- first rib
- axillary
- cephalic
- superior vena cava
- brachial
- basilic

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Subclavian

- Infraclavicular approach
- Anatomical Landmarks:
  - Midclavicular point
  - Lower border of clavicle
  - Triangle formed by sternal & clavicular heads of sternomastoid muscle with upper border of clavicle
**Subclavian**

- **Needle Insertion:**
  - 1 cm below midpoint of lower border of clavicle
  - Aim needle medially, towards the sternomastoid triangle (if not clearly defined, aim to suprasternal notch)
  - Advance needle posterior to the clavicle, keeping close to its posterior aspect
  - Maintain the needle & syringe parallel to coronal plane
Internal Jugular

- Anatomical Landmarks:
  - Carotid artery
  - Midpoint of sternomastoid muscle
  - Midpoint angle of jaw to suprasternal notch
Internal Jugular

- Needle insertion:
  - Midpoint of sternomastoid muscle
  - Lateral to carotid artery
  - Above level of cricoid
  - Angle 45° to skin
  - Aim towards ipsilateral nipple
Femoral Vein

- Anatomical Landmarks:
  - Identify femoral artery below inguinal ligament
  - Vein is medial to artery
  - “NAVELY”
Femoral Vein

Needle insertion:
- 1cm medial to artery, just below inguinal ligament
- Point tip cephalad and slightly lateral
- Angle 30° to skin
Upper limb Veins (PICC)

- Antecubital fossa or proximal portion of upper limbs
- Entering the superior vena cava (SVC)
- Length depends on patient size (30-70 cm)
Upper limbs veins (PICC)

- **Basilic**
  - Optimal
  - Largest diameter
  - Straightest route to SVC

- **Median cubital**
  - Smaller
  - Second best option
  - Direct path to basilic vein

- **Cephalic**
  - Narrows along the path
  - Angle when joints the axillary vein

**Ideal point of insertion**
Above the antecubital space

To avoid mechanical problems with arm bending
Procedural technique: Steps

- **Position patient:**
  - CVC – Jugular or subclavian
    - Trendelenburg 5 – 15 degrees and head rotation up to 30 degrees
  - PICC
    - Support upper limb
  - Femoral
    - Mild adduction lower limb

- **Sterile technique**
  - PICC: Tourniquet must be covered by sterile drapes

- **Local anaesthesia:** 1% lignocaine, 23-25 gauge needle
  - Usually 2-5mL jugular and femoral sites
  - Usually 8-10mL subclavian site
Procedural technique: Steps

- Check with landmark technique before US:
  - *Why would I do this if I have ultrasound available?*
    - To keep your skills if ultrasound **not** available
    - To train yourself to identify the correlation between US and landmark techniques
    - For IJ and femoral: place index finger of non-dominant hand on arterial pulse to diminish the risk of inadvertent artery puncture (arterial pulse most relevant anatomical landmark)
    - Be aware of unrecognised anatomical variability and vascular thrombosis using the “blind” landmark technique
Procedural technique:

Step: Real US guidance for needle insertion

- **Prepare US probe** → requires the assistant:
  - Linear array US probe (“vascular”), 6-10 MHz
  - Cleansing: Neutral detergent wipes (‘tuffie’)
  - Sterile coupling gel over the probe
  - Sterile sheath cover, including the cable

- **Scan** → with sterile covered probe on the sterile field:
  - Check US settings for optimal view (see *Basic knobology*):
    - gain, depth, position marker
  - Identify vessels – positioning in the center of the screen
  - Sterile coupling gel
    - Between probe footprint and sheath
    - Between sheath and patient’s skin
      - Avoid excessive slippery surfaces
  - Not recommended “marking” → it is a real time technique
    - Marking needle may produce haematoma and anatomical distortion

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Procedural technique: Step: Basic knobology – adjust settings

- **Gain**
  - Optimises the contrast between tissues displayed on the screen
    - White → solid tissues
    - Black → liquid

Excessive GAIN

Adequate GAIN

Too low GAIN
Procedural technique: Step: Basic knobology – adjust settings

- Depth
  - Vertical field of the image
    - Initial deep ultrasound interrogation
      - To establish anatomical landmarks
    - Decrease the depth to the smallest to display the area of interest
      - To improve resolution

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Procedural technique:
Step: Basic knobology – adjust settings

- **Position marker**
  - Orientation dot:
    - Generally on the top of the sector
    - Can be changed
  - Re-check touching or moving the probe
Procedural technique:
Step: Real US guidance for needle insertion

- **Operator holds the probe**
  - Non dominant hand
  - Rest your hand on the patient
    - To avoid sliding and muscle fatigue
  - **Avoid excessive pressure**
    - Collapses the vein and distorts the anatomy

- **Inject the local anaesthesia**
  - Enlarging wheal – hypoechoic area
  - Small “jiggle” of the needle to identify needle or artefacts
Procedural technique

CVC
Procedural technique:
Step: Real US guidance for needle insertion

- **Insert needle under real US guidance**
  - Dominant hand
  - **Needle bevel facing up**
    - Reduces impaction of the wire on posterior wall
  - Needle direction ~ 45 degrees
  - Needle close to probe footprint
    - Careful → avoid probe cover puncture

- **Techniques**
  - **Short axes** → indenting anterior wall of the vessel or artefacts
  - **Long axes** → needle seen if in the same US beam plane

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Procedural technique:
Step: Real US guidance for needle insertion

- **Aspiration** → flush of venous blood
  - Possible penetration → Short axes does not visualise properly posterior wall
    - Withdraw the needle slowly, aspirating until flush of venous blood
  - Hypovolaemic patients → compression - aspiration collapses the vein
    - Reduce the negative pressure during aspiration
    - Re-check your position in the vessel with US

- **Operator puts down the probe**
  - On the sterile field
  - Holding / stabilising the syringe – needle with dominant hand
    - Careful → Risk of displacing the needle
Procedural technique: Step: Seldinger technique for CVC

- Inserted needle under real US guidance

- Hold the needle and syringe
  - with non – dominant hand

- Disconnect / detach the syringe from needle
  - Carefully to prevent needle dislodgment
  - Briefly to prevent potential air emboli
  - Check for venous flush back
    - Risk of under recognise slow arterial blood flow if hypotension – hypovolaemia – shock
Procedural technique:
Step: Seldinger technique for CVC

- Progress / thread the wire into the needle:
  - Always maintain **full control of the wire**
  - Monitor for **arrhythmias**
  - Recognise **resistance** → consider
    - Pull back needle
    - Change angulation of needle
    - Twist wire
    - Possible vein valves
    - **Extra luminal: Transvenous perforation**
    - Transvenous arterial puncture
Procedural technique: Step: Seldinger technique for CVC

- Remove needle – Leave wire in situ
  - Do not leave needle unnecessarily
    - Risk of coughing – patient movements and mechanical complications
  - Always maintain full control of the wire
Procedural technique:
Step: US to check wire position for CVC

- **US scanning to verify wire position**
  - Short and long axes
  - May required “jiggling” the wire
    - Easier identification
    - Distinguishing vessel wall and wire
  - Before dilatation
    - Prevents inadvertent arterial dilatation
Procedural technique:
Step: Seldinger technique for CVC

- Make skin incision
  - 1-2 mm at the site of the puncture
  - Consider minimizing or avoiding incision if high risk of bleeding

- Remove coupling gel from skin
  - Slippery surfaces are difficult for dilatation
Procedural technique: Step: Seldinger technique for CVC

- **Advance dilator over guide wire:**
  - Follow **same insertion pathway** of the needle to avoid kinking the wire
  - Check **free wire movement** during dilatation
  - Dilate the tract (mostly subcutaneous tissues to decrease vessel wall and endothelial damage)

- **Remove dilator – Leave wire in situ:**
  - Always maintain **full control of the wire**
Procedural technique: Step: Seldinger technique for CVC

- **Thread catheter over wire**
  - Always keep control of the wire
  - Length according with patient and site of insertion

- **Remove guide wire**
  - Hold catheter still while pulling wire to prevent inadvertent catheter removal
  - Clamp lumen after removing the wire
    - Risk of cutting – bending the wire if clamped with wire inside the catheter
Procedural technique:
Step: CVC Securing - Dressing

- Secure catheter
  - 4 sutures
  - 2 sutures + “Stat Lock”

- Dressing
  - Sterile dressing
  - Ideally transparent to check entry site

- Dispose contaminated material and sharps safely
Procedural technique

PICC
Procedural technique: Seldinger technique modified for PICC

1. Inserted needle under real US guidance

2. Hold the needle and syringe
   - with non–dominant hand

3. Disconnect / detach the syringe from needle
   - Carefully to prevent needle dislodgment
   - Check for venous flush back
     - Risk of under recognise slow arterial blood flow if hypotension – hypovolaemia – shock
Procedural technique:
Step: Seldinger technique modified for PICC

4. Progress / thread the wire into the needle
5. Remove needle – leave wire
6. Thread dilator through the wire
7. Leave dilator – remove wire
Procedural technique:
Step: Seldinger technique modified for PICC

8. Progress / thread the catheter into the dilator:
   - Recognise resistance → consider
     - Pull back catheter
     - Change angulation of arm
     - Vascular thrombosis
     - Malposition
       - Ascending to neck vessels
       - Anomalous anatomy

9. Remove dilator / introducer – leave catheter in
Procedural technique:
Step: US to check catheter position for PICC

10. US scanning to verify PICC position
   - Short and long axes
   - Neck vessels and supraclavicular views
     - Recognizing ascending position before removing the sterile field
       - Allows pulling back and attempting reinsertion in sterile conditions
Procedural technique:
Step: PICC Securing - Dressing

11. Secure catheter
   - 2 sutures + “Stat Lock”

12. Dressing
   - Sterile dressing
   - Ideally transparent to check entry site

13. Dispose contaminated material and sharps safely
Confirmation of satisfactory completion

Methods:
- Immediate
- Mediate
- Delayed
Methods of confirmation of satisfactory completion:

- **Immediate**
  - Blood return from all lumens
  - Ultrasound

- **Mediate**
  - Pressure tracing
    - Especially useful if emergency need to use CVC
  - Blood gas

- **Delayed**
  - Chest radiograph for placement position and potential complications
Documentation
Documentation

- According with unit policies:
  - CLAB form
  - Medical records

- Relevant details:
  - Ultrasound findings
    - Vessel thrombosis identified
    - Significant anatomical variations
  - Difficulties during the insertion
  - Number of attempts and sites attempted

- Confirmation method used
CLAB: check list
Additional reading

- NEJMvcm055053 Jug.wmv
- NEJMvcm0801006 fem.wmv
- PICC Arrow Poster
Assessment

Please complete theoretical assessment by clicking on this link:

http://www.surveymonkey.com/s/centrallinetest