New-2-ICU

Safety in Training

CANDIDATE MANUAL

Revised February 2025

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Foreword

"I see and I forget. I hear and I remember. I do and I understand"[1]

The New-2-ICU course was set up in 2009 with a view to improving the safety of patients of on the intensive care unit (ICU). The European Working Time Directive, coupled with changes to postgraduate medical education has meant that doctors in training are now working on the ICU with less clinical experience than was the case previously. Furthermore, work on the ICU requires skills and knowledge which are often not transferable from other specialties. Doctors in training are placed on the ICU on-call rota as soon as their rotation begins, often without direct supervision; they have little or no time to be taught or to learn the skills which will make them able to work proficiently on the ICU or to manage dangerous or life-threatening situations competently until senior help arrives.

Such situations do arise on the ICU. Data from the fourth National Audit Project of the Royal College of Anaesthetists suggests that approximately 20% of all airway incidents occur on the ICU; these result in death or brain damage in 61% of occasions, being more serious than events occurring elsewhere in the hospital[2]. Furthermore, 46% of these events occurred 'out of hours' and as such a significant proportion of them were managed by doctors in training. In addition, we know that airway displacement and the serious consequences of it occur more frequently after (not during) the placement of the device, reinforcing the view that problems may occur when senior help may not be available[3]. These studies demonstrate the importance of competence in understanding at least the initial management of airway displacement for doctors working on the ICU.

Data has shown that simulation can improve many aspects of the care provided by ICU doctors. It can improve staff interactions, teamwork, decision making as well as performance in ICU specific tasks[4,5,6]. It allows realism in the rehearsal of the management of important and life-threatening clinical situations, whilst allowing this experience to be gained in a controlled environment[7]. The use of multimedia learning aids such as videos and lecture podcasts allows more time on the course for hands on practice, and our experience and has been that this further improves learning[8,9,1011].

The New-2-ICU course addresses many of these problems by applying modern, evidenced based teaching and learning. It was established in 2009 and has been running twice a year since then in the Severn Deanery (Bristol), with excellent feedback and positive staff and patient experiences as a direct result of the learning which people have acquired form the course. Our data suggests the course is useful, relevant, and improves skills and confidence amongst candidates, and has proven its worth in a number of tracheostomy emergencies in our region. Thank you for your commitment to the New2ICU course.

Welcome to the Intensive Care team. We hope you enjoy your time.

Andy Georgiou & Miguel Garcia Rodriguez
Course Creators

Lizzie Williams, Sara Bonfield & Aravind Ramesh
Course Directors

Course Programme

The New2ICU programme has two main phases; a pre-course phase and the course itself, which is held in person.

It is essential that candidates complete the pre-course phase as there are no lectures on the course, and the knowledge laid out in the pre-course phase is assumed during the course itself.

Pre-course phase of New2ICU

To complete the New2ICU course, candidates must first complete the pre-course requirements outlined below. These have several features which will advance you as doctors and will help us to continually improve the course we offer. Candidates must:

1. Complete the pre-course questionnaire available here: https://forms.gle/cq1sPCd8Q5gypiLQ9
2. Read this manual. It contains a wealth of basic knowledge to help doctors through their first few weeks on the ICU.
3. Watch this important video from the Royal College of Anaesthetists, available here
4. Watch the short New2ICU lecture videos on key ICU topics such as sepsis and traumatic brain injury, available here.

The New2ICU course

You will be sent details of when and where the course will be. You will be allocated into groups of broadly similar experience on the day of the course itself.

As with all sim courses, you'll get more out of it, the more you put into it. Don't be afraid to make mistakes and ask questions. We always learn more from our mistakes than we do from our performances that have gone swimmingly.

The rest of this manual focuses on the knowledge and skills which will support you during your ICU rotation.

1.0 Airway

1.1 Airway equipment

You should become familiar with the following airway equipment:

- Ambu/self-inflating bag and mask
- Waters' Circuit
- Facemask
- Nasopharyngeal airway
- Oropharyngeal airway (Guedel)
- Supraglottic airway (SGAs): laryngeal mask airway (LMA) +/- proseal airway (pLMA), igel
- Endotracheal tubes
- Capnography
- Yankauer sucker
- Laryngoscopes

Ambu or self-inflating bag

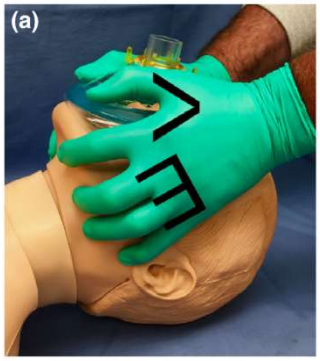
- Should be at every patient's bedside, or in the resus trolley and in the ICU grab bag.
- Does not require fresh gas flow to ventilate the patient (this makes it invaluable if there has been a failure of oxygen delivery).

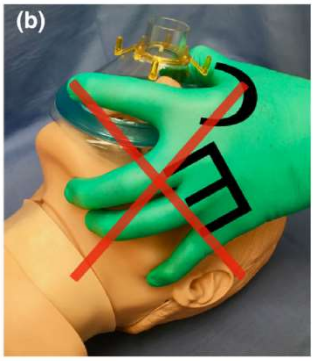
Waters' Circuit

- Requires a high flow of fresh gas to operate
- Can adjust PEEP using APL valve.
- Comes in a bag, in which are vital connectors which allow connection to wall or cylinder oxygen. Do not throw away the connectors!

Facemask

- Chose the correct size mask which should cover the nose and mouth.
- Use two-person technique to optimise effective ventilation





(a). Two-handed two-person bag-mask technique with the VE hand position; the second person squeezes the bag.
(b). The CE hand position, is a one-person technique and should be avoided if possible[12].

Nasopharyngeal and oropharyngeal airways

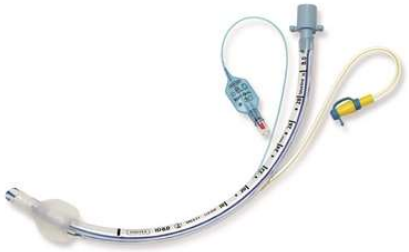
- Come in different sizes. Use the correct size for your patient.
- Take care to avoid airway trauma (particularly with NP airway).
- OP airway should be used to improve bag-mask ventilation and reduce gastric dilatation.

Supraglottic airway

- Can be used to aid oxygenation/ventilation during CPR, or as a rescue airway during failed intubation.
- The first generation of supraglottic airway (like the classic LMA illustrated on the left below) have been superseded by second generation supraglottic airways (like the igel illustrated on the right below, and the Proseal LMA). Second generation supraglottic airways have a gastric drainage port, a bit block and form a better seal in the pharynx, allowing higher ventilation pressures.
- Usually size 3-4 in adult females, and 4-5 in adult males.

Endotracheal tubes (ETT)

- Usually size 7.0 – 7.5 in adult females, and 8.0-8.5 in adult males.
- Should only be inserted by people trained to do so.
- Have a cuff to inflate to enable airway protection and to generate ventilation pressures. This is inflated with the pilot balloon.
- Most ICUs now use a tube with a subglottic suction port (yellow port). This aims to minimize secretions pooling above and then bypassing the cuff, which may cause ventilator associated pneumonia.

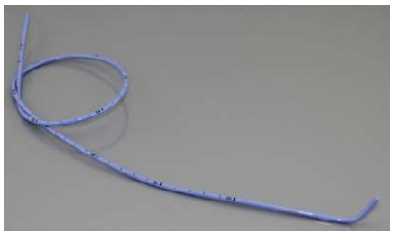


Laryngoscopes

- Used to aid endotracheal intubation.
- Default on ICU is usually videolaryngoscopy, but should have two blades available with working light sources.
- Adult videolaryngoscope blades: size 3 (usually appropriate for a female), size 4 (usually appropriate for a male), and hyperangulated (used where the larynx is very anterior and difficult to visualize with standard blades. Insertion of a tube when using a hyperangulated blade requires a modified technique to that usually used.

Bougie

- Used to aid endotracheal intubation.
- Are found in the packet on the airway trolley.
- Different materials are available.

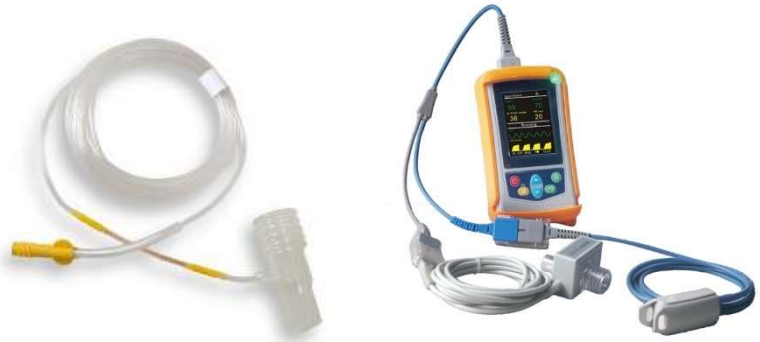


Yankauer Suction

- Suction tubing should be attached between the wall suction or portable suction units and the Yankauer. Always have a Yankauer immediately available during intubation.

Capnography

- Essential equipment to confirm presence of patent airway and correct placement of an airway device.
- Demonstrates presence of carbon dioxide in expired gases (end-tidal CO_2, $ETCO_2$) and gives a quantitative value.
- Can be used to assist with identification of presence of cardiac output or good-quality CPR during resuscitation.
- Intubation should NEVER occur without capnography.

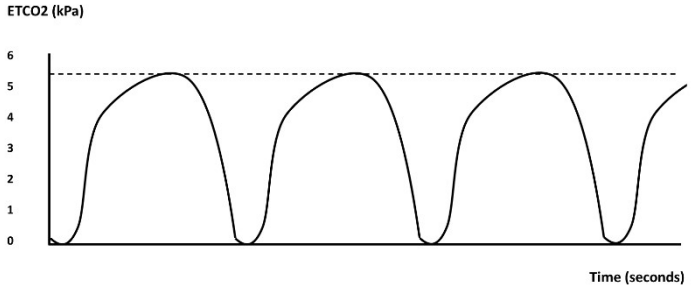


- It is essential to confirm the correct placement of an endotracheal tube at all times.
- For this reason, all ventilated ICU patients should have capnography attached and displayed at all times.
- It should be used during any airway management event, including bag-mask ventilation, and cardiac arrest.
- A lot of information can be obtained from the ETCO2 trace, including efficacy of ventilation, lung pathology, presence of cardiac output and effectiveness of CPR.

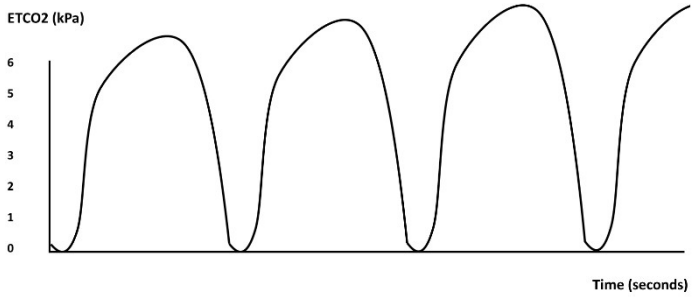
The Royal College of Anaesthetists have released a video describing the importance of capnography following the unfortunate deaths of two patients. The video (listed in the pre-course essential material) is again available here.

Examples of capnography traces:

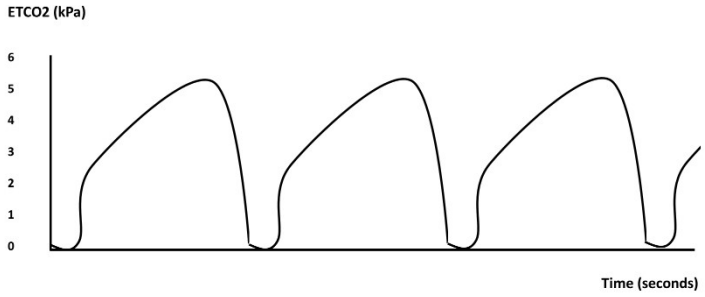
Normal ETCO2 trace



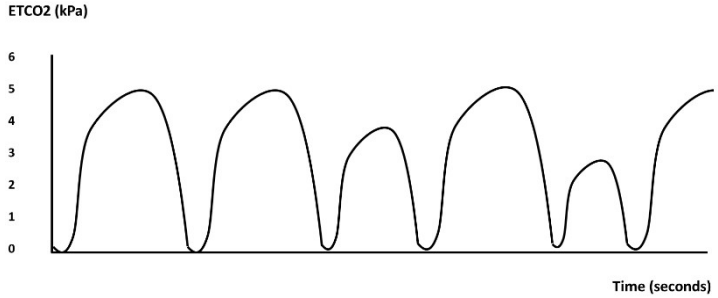
Increasing ETCO2 trace: hypoventilation, hypermetabolic



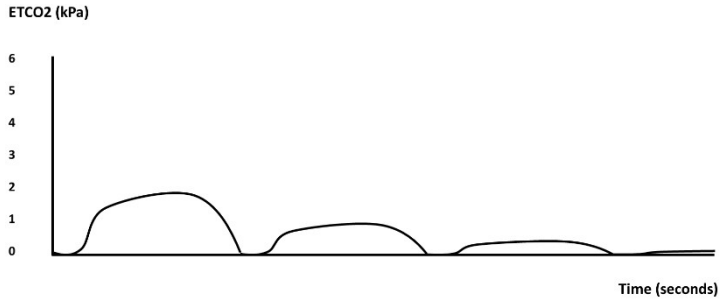
Upsloping plateau: obstructive picture eg bronchospasm



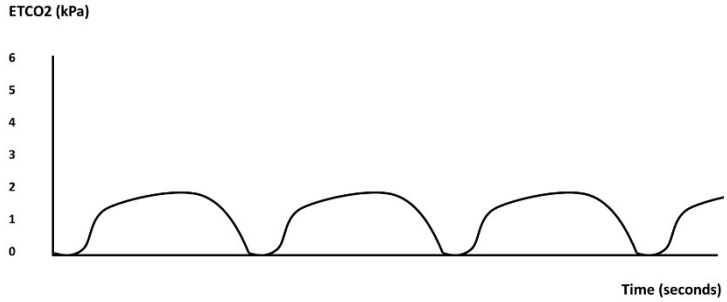
Variable trace: dyssynchrony with ventilator, coughing, etc



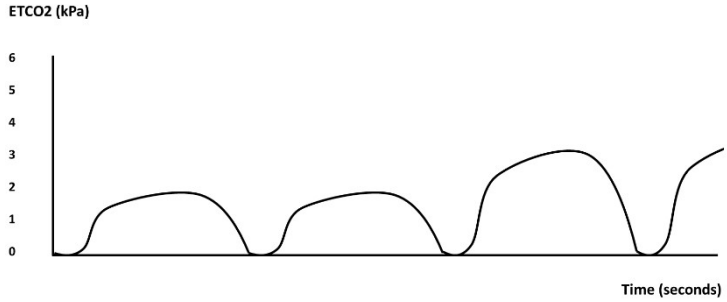
Attenuated trace: profound hypotension leading to cardiac arrest, possibly oesophageal intubation



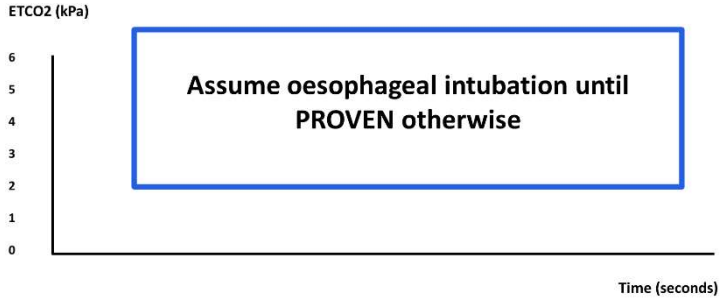
Cardiac Arrest: during cardiac arrest with CPR.
Cardiac arrest does not have a flat trace - approximate ETCO2 1.5 – 2kPa.



Return of spontaneous circulation following CPR



No trace: Flat line



No Trace = Wrong Place – assume oesophageal intubation and remove ETT
Other less common possibilities: completely blocked ETT, circuit or capnography tubing.

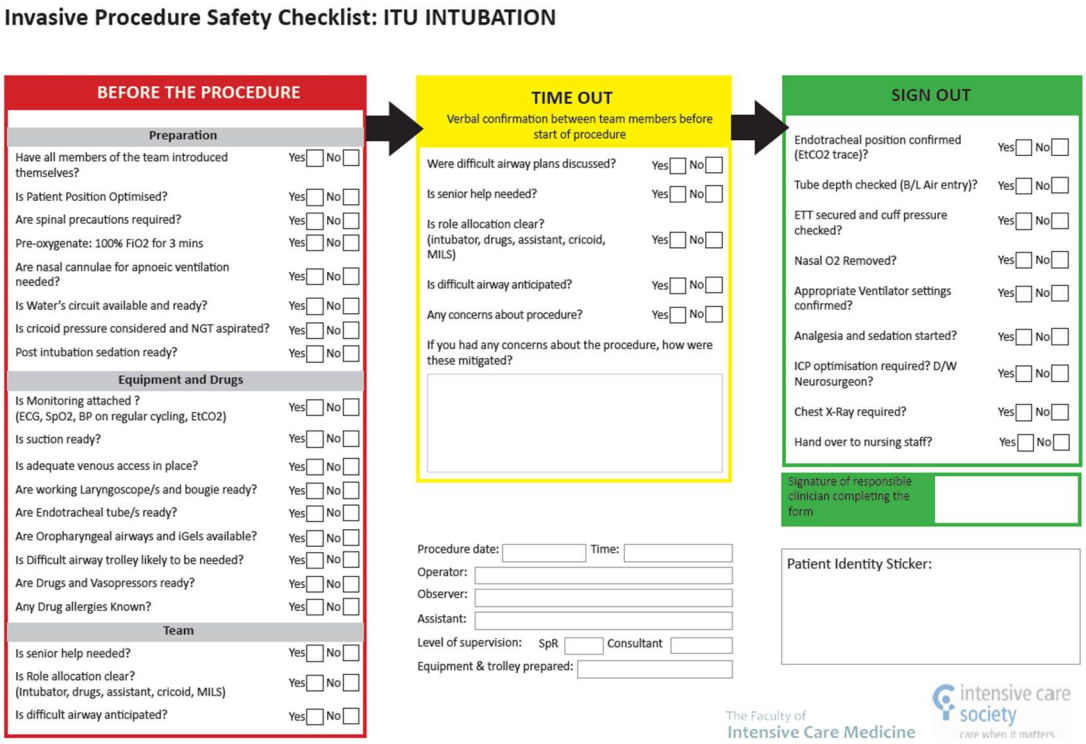
- If flat trace immediately after intubation, assume oesophageal intubation and remove ETT.
- If flat trace showing on ICU patient monitor who has been intubated for a while, check for accidental extubation in the first instance, then check equipment.

1.2 Checklist for tracheal intubation

Checklists for tracheal intubation have become the standard of care for intubations occurring outside of the theatre environment. This includes ICU, obstetrics and the Emergency Department. The national intubation checklist is available on the New2ICU website here, and is illustrated below for convenience.

It is designed to optimize preparedness, and to ensure all members of the team are aware of the procedure and the course of action following any anticipated complications.

It can be performed quickly and efficiently, and **does not** delay safe intubation.



Invasive Procedure Safety Checklist: ITU INTUBATION

BEFORE THE PROCEDURE

Preparation

Have all members of the team introduced themselves?	Yes ☐ No ☐
Is Patient Position Optimised?	Yes ☐ No ☐
Are spinal precautions required?	Yes ☐ No ☐
Pre-oxygenate: 100% FiO2 for 3 mins	Yes ☐ No ☐
Are nasal cannulae for apnoeic ventilation needed?	Yes ☐ No ☐
Is Water's circuit available and ready?	Yes ☐ No ☐
Is cricoid pressure considered and NGT aspirated?	Yes ☐ No ☐
Post intubation sedation ready?	Yes ☐ No ☐

Equipment and Drugs

Is Monitoring attached ? (ECG, SpO2, BP on regular cycling, EtCO2)	Yes ☐ No ☐
Is suction ready?	Yes ☐ No ☐
Is adequate venous access in place?	Yes ☐ No ☐
Are working Laryngoscope/s and bougie ready?	Yes ☐ No ☐
Are Endotracheal tube/s ready?	Yes ☐ No ☐
Are Oropharyngeal airways and iGels available?	Yes ☐ No ☐
Is Difficult airway trolley likely to be needed?	Yes ☐ No ☐
Are Drugs and Vasopressors ready?	Yes ☐ No ☐
Any Drug allergies Known?	Yes ☐ No ☐

Team

Is senior help needed?	Yes ☐ No ☐
Is Role allocation clear? (Intubator, drugs, assistant, cricoid, MILS)	Yes ☐ No ☐
Is difficult airway anticipated?	Yes ☐ No ☐

TIME OUT

Verbal confirmation between team members before start of procedure

Were difficult airway plans discussed?	Yes ☐ No ☐
Is senior help needed?	Yes ☐ No ☐
Is role allocation clear? (intubator, drugs, assistant, cricoid, MILS)	Yes ☐ No ☐
Is difficult airway anticipated?	Yes ☐ No ☐
Any concerns about procedure?	Yes ☐ No ☐

If you had any concerns about the procedure, how were these mitigated?

Procedure date: Time:

Operator:

Observer:

Assistant:

Level of supervision: SpR Consultant

Equipment & trolley prepared:

SIGN OUT

Endotracheal position confirmed (EtCO2 trace)?	Yes ☐ No ☐
Tube depth checked (B/L Air entry)?	Yes ☐ No ☐
ETT secured and cuff pressure checked?	Yes ☐ No ☐
Nasal O2 Removed?	Yes ☐ No ☐
Appropriate Ventilator settings confirmed?	Yes ☐ No ☐
Analgesia and sedation started?	Yes ☐ No ☐
ICP optimisation required? D/W Neurosurgeon?	Yes ☐ No ☐
Chest X-Ray required?	Yes ☐ No ☐
Hand over to nursing staff?	Yes ☐ No ☐

Signature of responsible clinician completing the form

Patient Identity Sticker:

The Faculty of Intensive Care Medicine

intensive care society

1.3 Drugs used for intubation

This is discussed in more detail in Section 5.

Commonly used drugs during intubation in the UK are:

Sedation:	Propofol, Ketamine, Midazolam
Opioids:	Fentanyl, Alfentanil
Muscle relaxation:	Rocuronium, Suxamethonium
Vasopressors:	Metaraminol, Adrenaline

1.4 Tracheostomies

The fourth national audit project of the Royal College of Anaesthetists identified that displaced tracheostomy tubes were the greatest cause of major airway related morbidity and airway related mortality in ICU, hence particular attention to this aspect of care during this course[2]. Two points were particularly noteworthy. Firstly, that obese patients were at particular risk of such events, and secondly that all patients on ICU were advised to have an emergency re-intubation plan.

Tracheostomies may be permanent or temporary, newly sited or well-established. Regardless of the reason or length of time they have been in place, all doctors working on intensive care units should be able to troubleshoot and deliver immediate emergency care for these patients.

Tracheostomies on ICU are usually placed to facilitate ongoing ventilatory care. The benefits include:

- Facilitating weaning of sedation and ventilation.
- Pulmonary toilet and improved oral care.
- Improved patient comfort, communication and daily living activity.
- Protection of the airway (e.g to avoid chronic aspiration) and potentially maintenance of the airway (in the event of airway surgery or swelling).

These tracheostomies are often performed percutaneously by intensivists on the ICU, but some are inserted surgically (e.g. patients with unfavorable anatomy). They are inserted with temporary intent but may stay in for several months, depending on a patient's recovery and progress. Other tracheostomies seen on ICU and around the hospital have been placed for airway or long-term ventilation concerns, for example following airway surgery.

In any patient with a tracheostomy, it is vital to distinguish patients who have normal upper airway anatomy from patients who do not. Patients who have normal upper airway anatomy can ultimately have their airway managed from the nose/mouth in the normal way in the event that a tracheostomy is displaced or removed. The same is not true for patients who do not have normal upper airway anatomy (e.g. patients who have had a laryngectomy). Unlike patients with a normal upper airway, patients who have had a laryngectomy cannot have their airway managed from the nose/mouth as the trachea is no longer in continuity with the nose/mouth. This vital distinction should be clear at each patient's bedspace so people attending in emergencies know how to manage an airway emergency. There are nationally approved bedhead signs which make this clear and these should always be on display behind the patient's bed. It is also highly advisable to have the appropriate displaced tracheostomy algorithm at the bedspace of any patient with a tracheostomy (see below). These are available on the New2ICU website here.

Displaced tracheostomy algorithms

A displaced tracheostomy algorithm was first devised by the New2ICU course creators in February 2009. Since then, there has been widespread recognition that an algorithm such as this can improve decision making and reduce cognitive burden on staff when faced with a tracheostomy emergency. The National Tracheostomy Safety Project (NTSP) has since published displaced tracheostomy algorithms which are available on their website here. We recognize that the NTSP algorithms are incredibly useful for staff from a wide variety of backgrounds, but in order to simplify the algorithms further and make them highly relevant only for staff who work on ICU (particularly junior staff), we have updated our New2ICU algorithms, and these are illustrated below. Staff who work on ICUs should understand which algorithms their unit uses and refer to that in the interests of consistency. We have been teaching the algorithms below for over 15 years and have found that staff who are new to the ICU can learn, adopt and apply them quicky, so they are placed here for reference and adoption where appropriate. You will have an opportunity to put these algorithms into practice on the course.

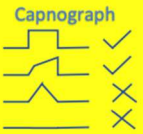
Tracheostomy (with own upper airway)

Royal United Hospitals Bath NHS
NHS Foundation Trust

RED FLAG SIGNS

Airway	Breathing	Circulation + Disability
Speaking despite cuff up Snoring Audible leak Increased need for air in cuff	Altered/abnormal capnography trace Ventilator alarm: obstruction Ventilator: ↓ minute volume Ventilator: ↑airway pressures ↑RR, ↓SpO, ↑$ETCO_2$, ↑ $PaCO_2$	↑HR ↓BP Distress/ agitation ↓GCS

Call for help and BLEEP 7333
100% oxygen – tracheostomy and face mask
Check capnograph trace for 'top hats'
Call for difficult airway trolley



Remove inner tube if present
Try passing suction catheter

Catheter passes

Attach Waters circuit, try two gentle breaths & look for…
- Capnography 'top hats' trace - OK
- Chest moving - OK
- Neck swelling – STOP ventilating

Catheter does NOT pass

Trache positioning Correct

Tracheostomy appears to be in the wrong place
Declare an EMERGENCY
"Displaced tracheostomy with own upper airway"

STOP AND THINK
Invite ideas and consider other causes:

Bronchospasm
Pneumothorax
Sputum plugging
Pneumonia

PATIENT STABLE

1. Request slim bronchoscope (3.8mm outer diameter) – by difficult airway trolley
2. Await senior help
3. Senior awake bronchoscopy via tracheostomy to visualise tracheal rings and confirm position

PATIENT UNSTABLE

1. Deflate trache cuff
2. Remove tracheostomy tube
3. Delegate one person to press hard on trache site with gauze
4. Manage airway from top with facemask oxygen, Waters circuit and Guedel airway
5. Request CMAC and emergency drugs
6. Prepare for intubation

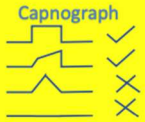
Laryngectomy (neck-only breather)

Royal United Hospitals Bath NHS
NHS Foundation Trust

RED FLAG SIGNS

Airway	Breathing	Circulation + Disability
Audible leak Increased need for air in cuff	Altered/abnormal capnography trace Ventilator alarm: obstruction Ventilator: ↓ minute volume Ventilator: ↑airway pressures ↑RR, ↓SpO, ↑$ETCO_2$, ↑ $PaCO_2$	↑HR ↓BP Distress/ agitation ↓GCS

Call for help and BLEEP 7333
100% oxygen via tracheostomy
Check capnograph trace for 'top hats'
Call for difficult airway trolley



Request slim bronchoscope (3.8mm outer diameter) – by difficult airway trolley

Remove inner tube if present
Deflate and re-inflate cuff
Try passing suction catheter

Catheter passes

Attach Waters circuit, try 2 gentle breaths & look for…
- Capnography 'top hats' trace  - OK
- Chest moving - OK
- Neck swelling – STOP ventilating

Catheter does NOT pass

Trache positioning Correct

Tracheostomy appears to be in the wrong place
Declare an EMERGENCY
"Displaced tracheostomy in a neck-only breather"

STOP AND THINK
Invite ideas
Consider:
Bronchospasm
Pneumothorax
Sputum plugging
Pneumonia

PATIENT STABLE

1. Prepare slim bronchoscope
2. Await senior help
3. Senior awake bronchoscopy via tracheostomy to visualise tracheal rings/confirm position
4. D/W on-call ENT if needed

PATIENT UNSTABLE

1. Deflate trache cuff and remove tracheostomy
2. Ventilate using paediatric facemask or LMA over stoma
3. Re-establish tracheostomy– load size 6.0 cuffed tracheal tube onto slim bronchoscope and railroad into position
4. OR insert bougie + railroad over size 6.0 tracheal tube
5. Contact on-call ENT registrar/consultant urgently

Tracheostomy tubes

There are many different kinds of tracheostomy tubes. Each patient should have spare tracheostomy tubes (and inner tubes) at their bedside, including one a size smaller than their current one. There should also be a tracheostomy bag/box with the patient at all times, which contains tubes and equipment required to re-insert a displaced tube if that is required. You should familiarize yourselves with the contents of these bags/boxes in your organization.

Tracheostomy tubes may have:
1. Cuff or no cuff
2. Inner tube or no inner tube
3. Adjustable flange
4. Fenestrations

Good resources for tracheostomy information are
https://tracheostomy.org.uk/
https://www.ccam.net.au/handbook/tracheostomy/

2.0 Breathing

2.1 Ventilation on ICU

There is no substitute to spending time on your unit, learning from the senior medical and nursing staff about ventilation. Each department has a different default ventilation strategy. However, there are basic principles of mechanical invasive ventilation that you should know, to be able to troubleshoot whilst on ICU.
If in doubt, ask for help!

Invasive ventilation

Invasive ventilation requires the patient to have an artificial airway (usually oral/nasal endotracheal tube or tracheostomy tube) and be provided with positive pressure ventilation. There are many modes of invasive ventilation, but they all come down to two main ways of delivering a 'breath' to a patient:

1. Volume control ventilation: delivery of a certain volume of gas to the patient. This will result in a variable peak pressure being applied to the patient's airway, depending on patient, pathophysiology and equipment factors.
2. Pressure control ventilation: delivery of gas under a certain pressure to the patient. This will result in a variable volume breath being delivered, depending on patient, pathophysiology and equipment factors.

Harm can be easily caused by invasive ventilation. We aim to avoid ventilator-associated lung injury by ventilating safely and appropriately. This aims to avoid these complications:

- Barotrauma – injury caused by excess pressure.
- Volutrauma – injury caused by excess volume.
- Atelectotrauma – injury caused by the cyclic opening and closing of alveoli during tidal ventilation. This commonly happens at the interface between normally aerated and collapsed lung zones.
- Biotrauma – trauma from inflammatory process triggered by the mechanical stress at the alveolo-capillary wall.
- Other harm: damage to airway, respiratory muscle weakness, haemodynamic compromise, oxygen toxicity (atelectasis, free radicals, neonates).

Ventilation terminology

Each manufacturer will have different terms for similar settings. The important thing is to understand the physiological basics.

FiO_2

- The fraction of inspired oxygen.
- Expressed as a decimal (0.6) rather than a percentage (60%).

PEEP (cmH_20)

- Positive end expiratory pressure.
- The pressure left in the lungs at end of expiration, keeping alveoli open.
- PEEP allows alveoli to expand more easily during inspiration and aims to reduce biotrauma.
- PEEP allows more time for oxygen to diffuse across the alveolar membrane into the capillaries.

Tidal Volume (mls)

- Abbreviated to V_t
- The volume of gas blown into the lungs during a normal breath.
- There is good evidence to show patients should be ventilated with a tidal volume of 6mls/kg of ideal body weight– see Section 2.3 LPV.

Inspiratory Pressure (Pinsp cmH_20)

- The pressure delivered by the ventilator during inspiration.
- Given on top of PEEP.

- The difference in the pressure between PEEP and Pinsp is the driving pressure, and this determines the V_t.

Peak Pressure (Ppeak cmH_20)

- The highest pressure reached during inspiration.
- This is usually the sum of PEEP + Pinsp, but there may be spikes in the peak pressure due to patient or equipment factors.

Plateau pressure (Pplat cmH_20)

- The pressure measured at the end of an inspiratory pause (when air flow into the lungs has finished). Unlike Ppeak, it is not affected by airway resistance.

Inspiratory to Expiratory ratio (I:E ratio)

- The proportion of the whole respiratory cycle (breath) spent in inspiration compared with expiration.
- In health, usually around 1:2.
- Can be altered to improve oxygenation or ventilation (CO2 removal).

Mean airway pressure (Pmean cmH_20)

- Mean pressure in the airways throughout the respiratory cycle.
- A strong contributor to oxygenation.
- Can be increased by increasing PEEP, increasing inspiratory time relative to expiratory time (the longer spent in inspiration, the higher the Pmean), and Pinsp. However Pinsp is usually fixed by the desire to deliver 6ml/kg ideal body weight.

Pressure support (PS cmH_20)

- The pressure applied to assist the patient during spontaneous (supported) breathing on the ventilator.

Ventilation modes

Different ventilator manufacturers use their own branding for these modes, but the principles remain the same.

Volume Control (VC)

- The tidal volume delivered to the patient is set by the user.
- The resulting inspiratory pressure is variable and is dependent on lung mechanics.

Pressure Control (PC)

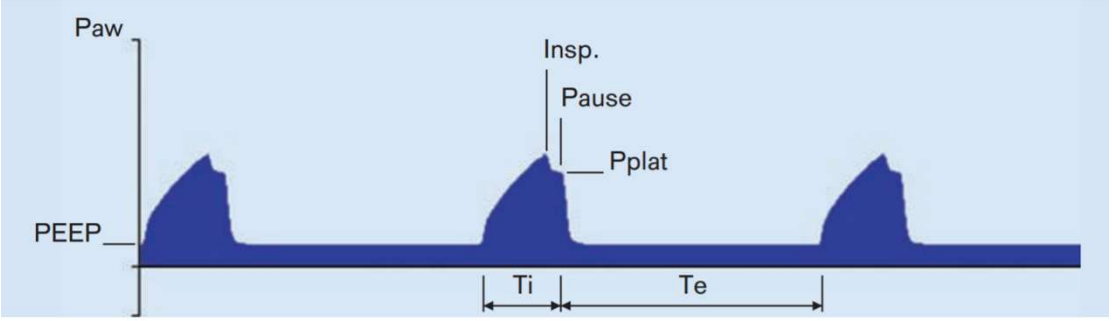
- The Pinsp is determined by the user. This remains constant.
- The resulting V_t is dependent on the patient's lung mechanics, and will change if these alter. A careful eye needs to be kept on the V_t as it is an important determinator of survival as described below.

Synchronised Intermittent Mandatory Ventilation (SIMV)

- The V_t and respiratory rate are set, along with a number of other variables.
- The patient can take spontaneous breaths during the expiration phase.
- Any spontaneous breaths will be 'supported' by PS.

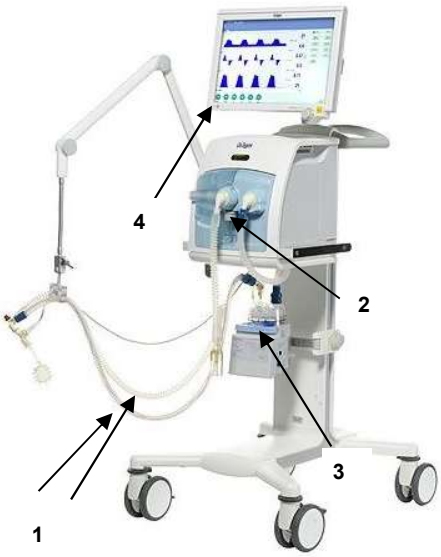
Pressure Control Volume Guarantee (PC-VG)

- The delivery of mandatory breaths to a set tidal volume, but delivered in a pressure control manner.



Further reading can be found here.

Ventilator Set Up



Components:

1. Inspiratory and expiratory limbs of ventilator tubing
2. Inspiratory and expiratory valves
3. +/- wet circuit humidification system. This ensures the gas going into the patient has been humidified.
4. Ventilator screen
5. +/- viral filter on expiratory limb

Setting up a ventilator

Ensuring the ventilator has passed all its checks and is ready to use is something that the nurses will do. It is the job of the doctors to enter the ventilator settings.

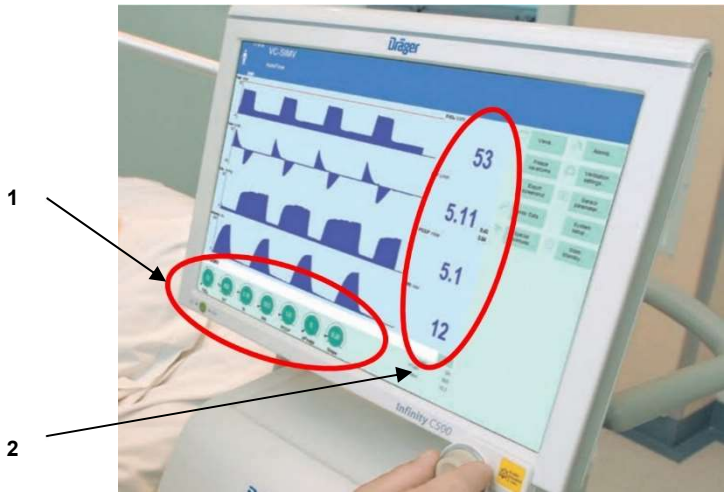
1. Dial up the settings that you would like the patient to receive (see image below for Drager ventilators). For a patient requiring mandatory ventilation:

- Oxygen concentration
- Tidal volume (in VC/PC-VG) or inspiratory pressure (PC)
- Respiratory rate
- I:E ratio
- PEEP
- Any pressure support that the patient may receive if they breathe spontaneously on top of the mandatory settings.

These are what we are aiming to give the patient.

2. Monitor what the patient is receiving (see image below for Drager ventilators):

This is not always what has been dialed up as it is reliant on the level of sedation, the patient synching well with the ventilator and the ability of the ventilator to deliver these breaths, which depends on patient size, position, pathology, sedation etc.



2.2 Improving Oxygenation and Ventilation

Increase Oxygenation	**Increase Ventilation (CO_2 removal)**
Improve mechanics Treat any underlying cause Increase FiO_2 Increase mean airway pressure: Increase PEEP Change I:E (increase I time) Prone ventilation ECMO	Improve mechanics Treat any underlying cause Ensure correct V_t (6ml/kg IBW) Increase minute ventilation: Increase respiratory rate Change I:E to ensure all available time is being optimally used for ventilation

2.3 Lung Protective Ventilation

Lung protective ventilation (LPV) is a strategy used to optimize ventilation for ICU patients in a manner which has been shown to improve outcomes. This is one of the best studied areas of intensive care medicine and the strategy is well known to ICU clinicians. The main components of LPV are:

1. Tidal volume 6 ml/kg based on ideal body weight (6ml/kg IBW).
2. Plateau pressure <30 cmH_2O.
3. Permissive hypercapnia (higher $PaCO_2$) tolerated as long as pH > 7.2.
4. PEEP increasing in line with FiO_2: ARDSnet suggests the use of PEEP/FiO_2 tables as shown here.

Further reading:
1. ARDSNet ventilation strategy here
2. BJA article on ARDS
https://academic.oup.com/bjaed/article/17/5/161/3782744
3. ATOTW ARDS
https://www.wfsahq.org/components/com_virtual_library/media/2ee4f27f10c91b341754032927d178cc-atow-411-00.pdf

2.4 Ventilator care bundles

The ventilator care bundle is a series of care interventions designed to reduce the risks or consequences of being on a ventilator. Some of these interventions reduce the risk of ventilator associated pneumonia (VAP), some do not.
Each region or department will have developed their own bundle, but the main components are likely to be:

- Raised head of bed to 30-45 degrees (minimises microaspiration).
- Daily sedation holds to assess readiness for extubation (decrease length of stay).
- DVT prophylaxis (as patients are so ill and immobile).
- Gastric ulcer prophylaxis (reduces risk of GI bleed but not necessarily mortality).
- Oral care such as oral 1% chlorhexidine (minimises microaspiration).

3.0 Circulation

A more in-depth description of the anatomy relevant to this section can be found here.

3.1 Arterial Line

3.1a Indications

- Continuous invasive blood pressure monitoring.
- Repeated arterial blood sampling. This can be helpful to assess changes in ventilation, acid/base balance, glucose, lactate.

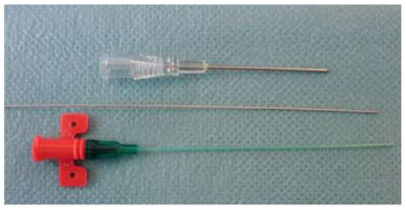
3.1b Contraindications

The only absolute contraindications to arterial cannula insertion are:

- Arterio-venous fistula.
- Localised sepsis at insertion site.

3.1c Types of lines:

1



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1. Seldinger insertion type (e.g. Vygon)
   Good for long stay patients, seem to kink less but can be messy to insert. Use inco pads if you want to make the ICU nurses happy!
2. Flowswitch: inserted using cannula technique.
   Less messy and reduced risk of blood loss due to on-off switch.
3. Abbocath: inserted using cannula technique.
   Some people choose to transfix the vessel, where the cannula is inserted into and then through the vessel, after which it is slowly withdrawn and when blood flows freely into the attached syringe, it is advanced into the artery.
   Easy to kink and will not 'unkink' so will often need replacing.
4. PiCCO (Pulse Contour Cardiac Output monitoring): inserted using Seldinger technique. Arterial cannula with thermistor that is used to monitor cardiac output following calibration by thermodilution and by deriving parameters from shape of the arterial waveform.
   Inserted preferentially in the femoral artery, but occasionally in the brachial artery (using the appropriate line length for each).

3.1d Insertion sites:

1. Usually radial – may be difficult if very hypotensive.
2. Brachial – should use ultrasound.
3. Femoral – should use ultrasound, will need longer and wider cannula.
4. Dorsalis pedis.

3.1e Insertion technique:

- Varies with type of cannula – seldinger vs cannula approach
- Helpful videos on e-Learning for Healthcare in Anaesthesia and Intensive Care Learning Modules indicated here:

My e-Learning: Anaesthesia (e-LA) Core Training - Clinical

e-LA Module 03 - Introduction to Critical Care General ICU Care
Procedures Arterial line: indications, insertion, complications
My e-Learning: Intensive Care Medicine (e-ICM)
Module 6 Procedures, Investigations and Monitoring in ICM
01 Procedures 02 Vascular Access
Arterial Lines: Technique of Insertion

Whichever site you choose, and whichever cannula type you use consider the following:

- Take time to prepare patient and equipment correctly – inco pads will keep your ICU nurse happy.
- Consider USS if poorly palpable pulses.
- Use local anaesthetic infiltration in awake patients.
- Maintain asepsis: 2% chlorhexidine/isopropyl alcohol to skin, fenestrated drape, sterile gloves and plastic apron.
- Ensure full use of checklist and documentation as per LocSSIP.

ALWAYS ensure that the flush bag attached is 0.9% sodium chloride. The flush bag should never contain glucose. Glucose in the flush line can lead to erroneously high glucose readings, the response to which is to increase the dose of insulin, which the patient of course does not need. This can lead to neuroglycopenic brain injury.

A note on Allen's test:

- Used to confirm adequate ulnar artery circulation to maintain hand perfusion in event of trauma/thrombosis to cannulated radial artery.
- Occlude both radial and ulnar artery for 1 minute, release and should see reperfusion of hand within 6 seconds.
- No evidence to show positive correlation with actual perfusion or that it prevents ischaemia and most clinicians do not routinely perform it.

3.1f Complications

Equipment related

- Loss of guidewire if using seldinger technique.
- Disconnection:
  - At cannula or at transducer level.
  - Can cause catastrophic haemorrhage if not recognized.
- Incorrect flush solution: **must be 0.9% NaCl** or heparinised saline **NEVER** dextrose.
  - High index of suspicion if persistently high blood sugars on ABG despite insulin administration.
- Inadvertent intra-arterial injection: ensure good labelling as arterial line.

Medical

- Thrombosis.
- Infection – less common than CVC infection but still possible.
- Distal ischemia.
- Haemorrhage.

3.1g Troubleshooting

The arterial cannula is attached to an appropriate transducer system by a short length of manometer tubing. Continually flushed by pressurised 0.9% NaCl (NOT dextrose).
Ensure transducer is at correct height:

- Level of 4th intercostal space (or at tregus for neuro patients).
- Transducer below the heart – falsely high arterial BP.
- Transducer above the heart – falsely low arterial BP.

What do we mean by 'zeroing'?

- The system needs to be calibrated to atmospheric pressure.

- This is done by zeroing the system when the transducer system is turned “off to the patient but open to air” (use of three-way tap).

What do we mean by a ‘damped’ trace?

The response in the system is too slow – can be caused by clot forming in the system or a kink in the cannula.

- Ensure system flushes easily.
- Ensure no air bubbles in tubing.
- Ensure flush bag correctly pressurized.
- Ensure cannula not kinked.

If problems persist despite these simple checks then seek senior advice

A flat arterial line trace may be an erroneous reading but never assume this- it may actually be due to cardiac arrest:

- Look for other signs of adequate circulation: heart rate and rhythm, $ETCO_2$, NIBP, palpable pulses.

3.2 Central venous line

For detailed instructions- see the CVC insertion guide on the New2ICU website.

3.2a Indications

Intravenous access:

- Patients on ICU require multiple drugs (often by infusion) simultaneously for long periods of time.
- Often have poor peripheral access.
- Many drugs given on ICU are unsuitable for peripheral administration.
- Inotropes and vasoactive drugs can cause localized necrosis and need to be given at a precise and reliable rate.
- TPN and hyperosmolar fluids cause phlebitis.

Therapeutic care:

- Enable renal replacement therapy, plasma exchange, transvenous pacing.

Monitoring pressures:

- CVP rarely used as an isolated number but a trend can be used to monitor changes in clinical state, e.g. evolving tamponade or right heart failure.
- Measuring central venous oxygen saturations ($ScvO_2$) to measure oxygen flux – balance between oxygen delivery and consumption.
- Thermodilution techniques (PiCCO) for measuring cardiac output.

3.2b Contraindications

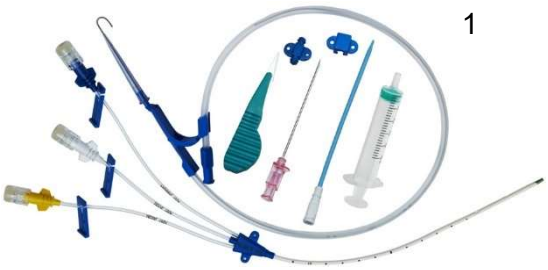
Absolute:

- Active infection at insertion site.
- Anatomical reason.

Relative:

- Coagulopathy.
- Thrombus in target vessel.
- Site specific (e.g. co-location with pacing wire).

3.2c Types of lines:



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1. Standard central line (7Fr) – usually 3-5 lumens, 16cm or 20cm length.
2. Vascath (14.5Fr) – two lumens, 16cm or 20cm length (used almost exclusively for renal replacement therapy).

Use a checklist. The national CVC insertion checklist is available on the New2ICU website and is shown below.

INVASIVE PROCEDURE SAFETY CHECKLIST: CVC Insertion

The Faculty of Intensive Care Medicine — Intensive Care Society

BEFORE THE PROCEDURE		
Any known drug allergies?	Yes ☐	No ☐
Coagulation checked?	Yes ☐	No ☐
Is all equipment available? (including ultrasound if applicable)	Yes ☐	No ☐
Sterility of operator (hands scrubbed, appropriate personal protective equipment worn)	Yes ☐	
2% Chlorhexidine Gluconate / 70% isopropyl alcohol formulation (Chloraprep 2%) applied to procedure site and allowed to dry?	Yes ☐	
Use a large drape to cover the patient in a sterile manner	Yes ☐	

TIME OUT Verbal confirmation between team members before start of procedure		
Is patient position optimal?	Yes ☐	No ☐
All team members identified and roles assigned? (assistant to provide prompt for wire removal during procedure)	Yes ☐	
Correct line ready / integrity of line checked	Yes ☐	
Any concerns about procedure?	Yes ☐	No ☐
If you had any concerns about the procedure, how were these mitigated?		

SIGN OUT		
Correct injection site caps placed using sterile technique	Yes ☐	
Sterile dressing	Yes ☐	
Guidewire removed?	Yes ☐	No ☐
Chest X-Ray required/ordered	Yes ☐	No ☐
Any adverse events? (Documented in adverse events Log)	Yes ☐	No ☐
Transduce CVC CVP waveform present Record CVP - mmHG If any concerns perform paired CVC gas and ABG. pO_2 CVC = pO_2 ABG =	Yes ☐	No ☐

Procedure date:
Time:
Operator:
Observer:
Assistant:
Level of supervision: SpR ☐ Consultant ☐
Equipment & trolley prepared:

Patient Identity Sticker:

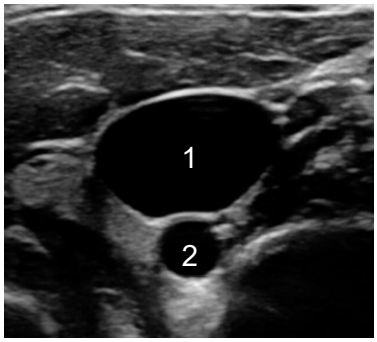
Signature of responsible clinician completing the form

3.2d Insertion sites:

1. Internal jugular - most commonly used, right sided is usually first choice. Good balance of risk of insertion and infection risk.
2. Femoral – lower risk of insertion but higher infection risk, difficult in obese patients.
3. Subclavian – higher risk of insertion but lower infection risk, technically more challenging to insert, difficult to compress in case of inadvertent arterial puncture.

3.2e Insertion technique

For a full description refer to a dedicated text such as the CVC insertion guide on the New2ICU website available here, or a formal text such as this.
NICE recommend the use ultrasound for all central line insertions reference.



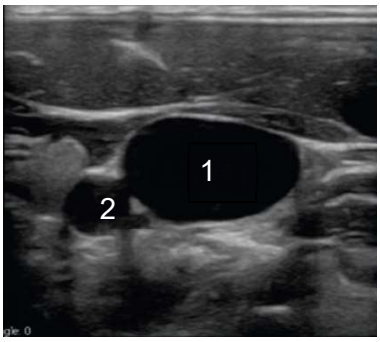


Image 1 Image 2
Ultrasound image of right internal jugular vein (1), and common carotid artery (2).

Use ultrasound to find the best location for insertion. Image 2 would be preferable as the artery is to the side of the vein and therefore less likely to be inadvertently punctured.
Always visualise your needle tip on the US image to be confident about how far in the needle is (i.e. avoid misjudging the depth to which the needle has been inserted).
Ultrasound the wire within the correct vessel before dilation.

ALWAYS ensure that the flush bag attached is 0.9% sodium chloride. The flush bag should NEVER contain glucose.
Whichever site you choose, and whichever line you use consider the following:

- Take time to prepare patient and equipment correctly – inco pads will keep your ICU nurse happy.

- Always use ultrasound.
- Use local anaesthetic infiltration in awake patients.
- Maintain sterile conditions: 2% chlorhexidine/isopropyl alcohol to skin, fenestrated drape, sterile gown and gloves, hat, mask, sterile ultrasound probe cover.
- Ensure transducer and flush line are ready to go before you start procedure.
- Ensure full use of checklist and documentation as per LocSSIP (including pre-procedure checks).

3.2f Complications

Early

- Arrhythmias
    - At time of insertion – usually due to myocardial irritation by guidewire and resolved by withdrawing wire (this is not innocuous- patients have arrested because of this complication). If persists, line may be in too far.
- Arterial puncture
    - Ultrasound minimizes risk.
    - Puncturing with needle is not a huge problem unless patient is coagulopathic. This needs 5-10 min compression.
    - Dilating and inserting the line into an artery is a problem. If this happens, alert your senior and refer the patient for percutaneous endovascular or surgical repair.
    - Usually obvious – bright red blood in the insertion syringe, but if in doubt a blood gas and/or transducing the line will confirm. See 3.2i.
- Pneumothorax.
- Bleeding - at insertion site.
- Nerve injury – rare.
- Air embolism – head down position minimizes air entrainment as venous system engorged, but can occur if caps/bungs/3 way taps are improperly connected. It is your responsibility to ensure all are appropriately connected before you leave the bedside.

Late

- Thrombosis.
- Pericardial tamponade – rare, due to atrial puncture if line too far in.
- Infection – consider removing all lines when no longer required, monitor site, be aware of duration since insertion.

3.2g Troubleshooting

You have an important role in helping to manage lines and minimise complications:

- Diligent asepsis if accessing line.
- Assessment of invasive lines forms part of daily check on ICU.
- Ensure you know how long the line has been present and examine site, ensure needle free access on all lumens.
- Lines do not have to be changed after a certain amount of time. If the site looks infected and/or there are raised inflammatory markers, then consider the line as a source of infection.
- If concerns regarding line sepsis they must be removed.
- Know how to assess correct position on CXR.
- Be familiar with the difference between arterial and central venous waveforms so you feel comfortable that line is correctly sited.
- If called to assess a central line because 1 or more lumens are not aspirating or flushing freely then label the blocked lumen and seek senior advice.
- If a dedicated lumen has been labelled as for TPN then this lumen should not be used for anything else.

- Central lines can leak around their insertion site. If asked to review, ensure patient appears to be stable from a haemodynamic and sedation perspective, and discuss with senior for further advice.

3.2h Central line care bundle

A bundle employed to reduce the risks of central lines:

- Surgical scrub hand hygiene, gown, gloves, hat, mask.
- 2% chlorhexidine in alcohol for skin antisepsis.
- Maximal barrier precautions before insertion.
- Optimal catheter site (subclavian is lowest risk, femoral route the highest).
- Aseptic access technique.
- Daily review of central line necessity with prompt removal of unnecessary lines.
- Education.

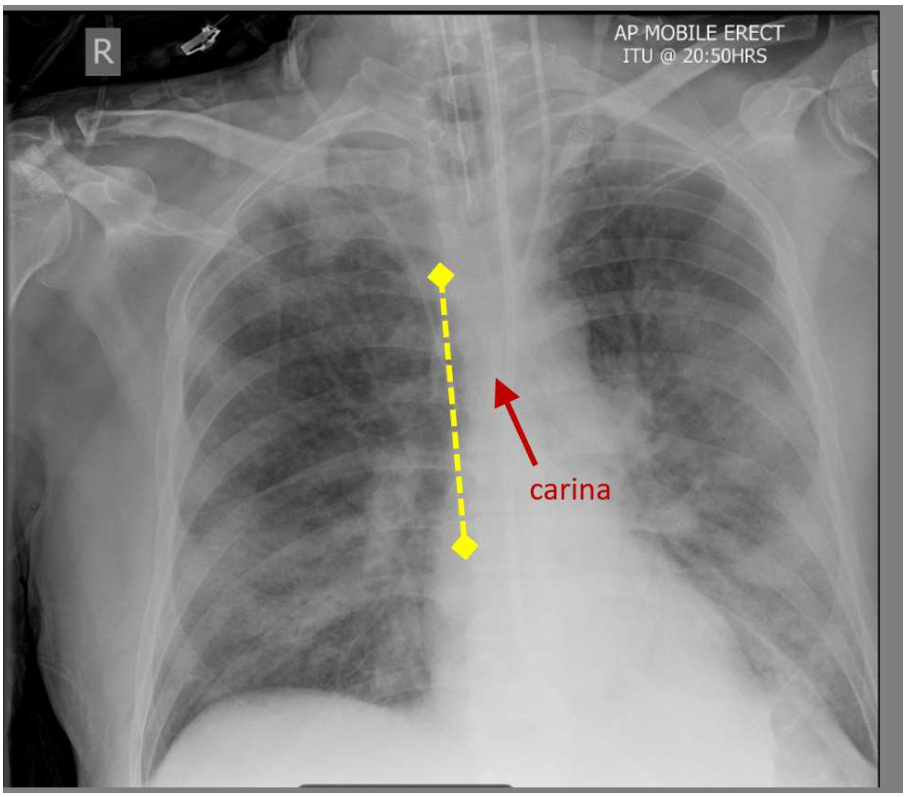
Always follow local protocols and document clearly (the national checklist has a second page with appropriate documentation, but your unit will have its own way of documenting insertion).

3.2i Confirming central venous line position

There are four important aspects of confirming correct position of a central line:

1. Use of ultrasound to confirm guidewire in the vein during insertion.
2. A blood gas taken immediately after insertion of line which confirms venous blood. This should be matched with an arterial blood gas for comparison.
3. A transduced venous waveform with appropriate pressure (usually 0-20mmHg).
4. Correct position on a CXR (if placed via the internal jugular or subclavian vein):

- CVL tip should be in the superior vena cava (ie to the right of the trachea and not crossing it).
- Within 3cm above or below the carina.



4.0 Sedation and delirium

4.1 Sedating drugs on ICU

There are many reasons patients are sedated on ICU, and the reasons for sedation help us to decide which drugs to use. Each ICU will have their own protocols so you should become familiar with those, but the basics of the main drugs used can be found in section 5.

Commonly used drugs include:

Sedation:	Propofol, midazolam, clonidine, dexmedetomidine.
Analgesics:	Alfentanil, morphine, remifentanil.
Muscle relaxants:	**NOT SEDATION** but used alongside appropriate sedation to facilitate muscle relaxation. Rocuronium, atracurium.

4.2 Role of sedation

Sedation is most commonly used to:

1. Facilitate placement and tolerance of endotracheal tube.
2. RASS).Facilitate mechanical ventilation and improve compliance.
3. Reduce oxygen consumption.
4. Enable procedures and critical care to be delivered comfortably for patients.
5. Maintain comfort/humanitarian.
6. Control of raised intracranial pressure.
7. Management of neurological disturbance (seizures, agitation).

Despite appropriate use, sedation can have significant adverse effects. These include:

1. They may lengthen mechanical ventilation and ICU stay.
2. They may promote critical care weakness/neuromyopathy.
3. Creating or worsening cardiovascular instability.
4. Impeding the assessment of neurological function.
5. Contribute to delirium.

4.3 Management of sedation

Appropriate management of sedation is essential to reduce at least some of the above adverse effects. The general consensus is that minimizing sedation where possible, is preferable for most ICU patients.

General concepts in sedation management include:

1. Daily assessment of sedation levels (see below).
2. Targeting sedation to a sedation target (see below).
3. Daily sedation breaks (interruption in sedation or 'sedation hold').

Sedation Assessment

- The most commonly used scoring system is the Richmond Agitation-Sedation Score (RASS).
- Score from -5 (unrousable) to +4 (combative).
- Ideal sedation is -2 to 0 for most ICU patients, although certain patient groups require deeper sedation (proned patients, patients with raised ICP).
- Sedation aims should be discussed and documented daily on ward rounds.

Score	Term	Description
+4	Combative	Overtly combative or violent, immediate danger to staff
+3	Very agitated	Pulls to remove tubes or catheters, aggressive behaviour toward staff
+2	Agitated	Frequent non-purposeful movement, fights ventilator
+1	Restless	Anxious, apprehensive, not aggressive
0	Alert and calm	Spontaneously pays attention
-1	Drowsy	Not fully alert, but has sustained awakening, with eye contact, to voice (more than 10 seconds)
-2	Light sedation	Briefly awakens with eye contact to voice (less than 10 seconds)
-3	Moderate sedation	Movement, but no eye contact, to voice
-4	Deep sedation	No response to voice, but movement or eye opening to physical stimulation
-5	Unrouseable	No response to voice or physical stimuli

Sedation Holds

These should be done daily, when medically appropriate, and ideally at the beginning of the day. They should be discussed on the ward round.
The possible benefits of sedation hold include:

- Decreased time to spontaneous breathing on ventilator.
- Decreased ventilator time.
- Decreased length of ICU stay.
- Decreased use of vasoactive drugs.
- Increase likelihood of successful extubation, and as such decreased risk of tracheostomy.
- Decreased delirium and psychological adverse effects.

They should be done with careful supervision as there is a risk of accidental or unplanned self-extubation or removal of lines/tubes/drains. They also significantly increase nursing workload.

4.4 Delirium on ICU

Definition

A disturbance of consciousness with inattention accompanied by a change in cognition or perceptual disturbance that develops over a short period of time and fluctuates over time. Inattention is one of the hallmarks and pivotal features of delirium.

Delirium on ICU is very common (some literature describes it affecting up to 80% of ICU patients). It is associated with increased morbidity and mortality (it is likely that the delirium is a marker of severity of illness as opposed to it causing mortality directly) and has significant effects on the patient's long- term recovery.
There are three types of delirium

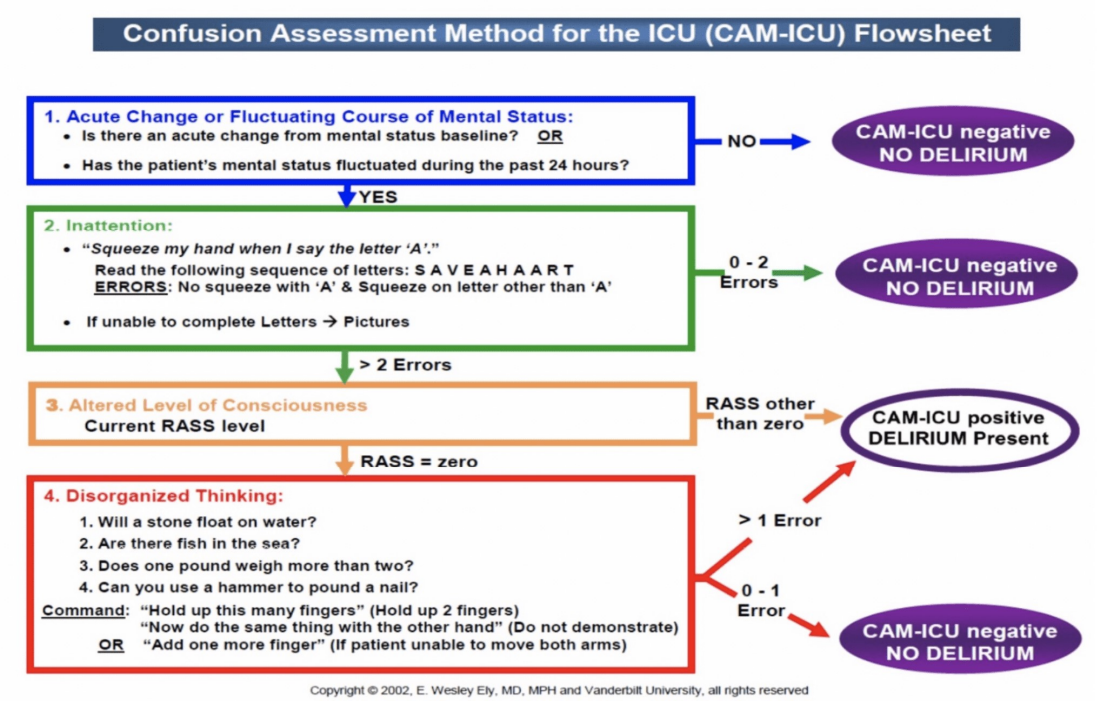
1. Hyperactive: agitation, restlessness, aggression, removal of tubes/lines.
2. Hypoactive: withdrawal, flat affect, inability to engage, lethargy, decreased responsiveness.
3. Mixed: fluctuation between hyper- and hypoactive delirium.

Hypoactive and mixed are most common on ICU, although can be hardest to recognize.

Assessment of delirium

- Maintain high index of suspicion in all patients.
- Identify risk factors present in each patient:
    - Pre-existing factors: age, cognitive impairment, alcohol/drug/nicotine use, hypertension, emergency admission.
    - ICU factors: increased severity of illness, mechanical ventilation, metabolic acidosis, coma, sepsis, steroids, benzodiazepines.
- Formally assess at least daily.

Formal assessment of delirium is undertaken using the Confusion Assessment Method for the ICU (CAM-ICU) scoring tool:



4.5 Management of delirium on ICU

Management of delirium is incredibly hard and very different to ward patients. Hyperactive delirium with agitation and pulling of tubes and lines can be fatal in ICU patients, and therefore we may move to pharmacological or restraint management strategies earlier than you would on the ward. Where hyperactive delirium is not present, sedation should be avoided.

Non-pharmacological measures for prevention and management of delirium:

- Daily assessment using bedside tools (CAM-ICU).
- Repeated reorientation of patients.
- Provision of cognitively stimulating activities for the patient multiple times a day.
- Target a day/night routine.
- Promote sleep hygiene through non-pharmacological means: lights down, alarm volumes reduced, eye mask, ear plugs (and ask patient what is effective!).
- Early mobilization activities.
- Timely removal of catheters and physical restraints.
- Use of eyeglasses and magnifying lenses, hearing aids and earwax removal.
- Early correction of dehydration.
- Excellent analgesia through a scheduled pain management protocol.
- Minimization of unnecessary noise/stimulation/observations.
- Ask patients each day if any concerns with hallucinations, confusion etc.
- Explain it to family and encourage engagement with above.

Pharmacological measures for prevention and management of delirium:

- Review current medications:
    - Remove daytime sedation agents.
    - Review opioid analgesia.
    - Review anticholinergic drugs.
- Use of non-opioid analgesia ideal.
- Avoid benzodiazepines.
- Melatonin to promote sleep.

Medication options for treatment:

- Haloperidol:
    - For rescue: 0.5 – 2mg IV bolus (every 5 mins, up to 20mg).
- Quetiapine
    - Commence if patient reports hallucinations or if rescue therapy used consider evening only initially so as not to sedate during day. Start at 25mg at 1800 or BD.

Other medications used on ICU for light-moderate sedation, management of delirium and aiding sedation weaning:

- Clonidine.
- Dexmedetomidine.

5.0 Drugs on Intensive Care

5.1 Sedative Drugs

	Propofol • Anaesthesia for intubation and continual sedation. • Given as bolus or infusion. • Two concentrations (1% 10mg/ml and 2% 20mg/ml). • Infusion rates very variable. Do not exceed 5mg/kg/hour. • Initial bolus dose for additional sedation 10-20mg. • Causes severe hypotension in very sick patients. • Can cause propofol infusion syndrome (PRIS) with prolonged infusions at >5mg/kg/hour, particularly if young (especially children), male, head injury and requiring noradrenaline.
	Midazolam • Sedation on ICU, and for management of seizures. • When given as prolonged infusion in ICU, will increase wake up time compared with propofol. • Increases delirium. • Commonly used in children as an alternative to propofol.

5.2 Sedative Adjuncts

Opioids
Commonly used as part of sedative regimen to reduce the amount of sedating agent required.

- Can all cause bradycardia.
- Can all cause respiratory depression – this may be beneficial to facilitate ventilator synchrony.

Morphine

- Long acting (slow onset and offset).
- Less titratable.
- Used in younger children when prolonged propofol infusions should be avoided.

Alfentanil

- More titratable than Morphine with good effect from bolus.
- Short context sensitive half life- that means it wears off quickly even if it's been infused for a long time.

Remifentanil

- Very quick onset and offset.
- Extremely short context sensitive half life- that means it wears off very quickly even if it's been infused for a long time.
- Used for light sedation with NIV/delirium/pre-extubation.
- Should never be bolused.

α2 agonists
Have analgesic, sedative and anxiolytic properties. Can cause hypotension.

- Good for patients with/at risk of alcohol withdrawal, weaning from long-term ventilation.
- Reduced delirium compared to benzodiazepines.

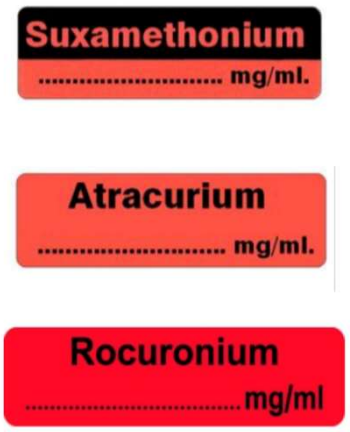
Clonidine

- Can be given as bolus or infusion.
- Can be given IV or enterally.

Dexmedetomidine

- More expensive – consultant decision only.
- Given as IV infusion.
- Needs to be uptitrated to effect.

5.3 Neuromuscular blocking agents



Muscle relaxants: should **only** be used once appropriately sedated.
Used for the following reasons:

- Intubation.
- Synchronisation with ventilator, improving ventilation/oxygenation.
- Prior to proning/transfer to prevent coughing/movement that could cause accidental extubation.

All have significant potential adverse effects.

Suxamethonium

- Caution in critical care patients (causes potassium release).
- Only used as bolus.
- Generally superseded by rocuronium.

Rocuronium

- Given by bolus.
- Now more commonly used for intubation.
- Requires liver and renal function to metabolize and excrete.

Atracurium, cisatracurium

- Given as bolus, but more commonly by infusion.
- Prolonged infusions can contribute to critical care neuromyopathies.

5.4 Drugs used for intubation on ICU

Sedative:	Ketamine 1-2mg/kg (caution with different concentrations). Propofol with caution and as directed by senior, due to risk of severe hypotension and cardiovascular collapse.
Opioid:	Fentanyl 1-3mcg/kg or Alfentanil as directed by senior. Optional depending on patient's physiological status.
Muscle relaxant:	Rocuronium 1mg/kg.
Emergency:	Metaraminol 0.5mg/ml (10mg into 20ml). Adrenaline 10mcg/ml.

You may hear the term "3:2:1" when discussing emergency drugs. This refers to pre-hospital protocols of 3mcg/kg fentanyl, 2mg/kg ketamine and 1mg/kg rocuronium. This can be adapted to 1:1:1 in haemodynamically unstable patients, and if very haemodynamically unstable- avoid fentanyl/alfentanil all together.

Suxamethonium is now rarely used as a muscle relaxant in critically unwell patients due to:

1. Risk of hyperkalaemia.
2. Risk of desaturation with muscle fasciculations.

3. Shorter-lasting intubation conditions which complicates a difficult airway.
4. Lack of benefit of 'quick reversal' in patients who are critically unwell.

Sugammadex is a drug which reverses rocuronium, but how useful this is in critical care is a point of debate.

5.5 Cardiovascular drugs

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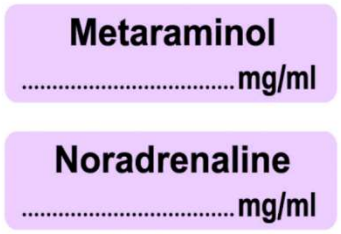
<td> 

 
</td>
<td>Vasopressors
Increase blood pressure by increasing peripheral vascular resistance. Generally this should only be done once the patient is euvolaemic.

Metaraminol
• Can be used peripherally.
• Can be bloused 0.5-1mg.
• Often used initially in theatre / resus for this reason.
• Usually diluted to 0.5mg/ml but can get pre-diluted ampules so check the concentration you have.

Noradrenaline
• Usually used centrally or (if diluted appropriately) can be given peripherally.
• Should never be given as a bolus.
• Central use usually follows confirmation of the central line position (see 3.2i).
• As one syringe nears completion, another is started to avoid a pause in delivery during switchover. This is called "double pumping" and is something the nurses do.
• Some units use ml/hr, others use mcg/kg/min.
• Standard preparations are 4mg, 8mg or 16mg in 50ml (single, double or quad 'strength').

Vasopressin
• Usually used with other vasopressors such as noradrenaline, allowing a reduction in the dose of that drug.
• Given by continuous infusion of up to 0.04units/min.</td>
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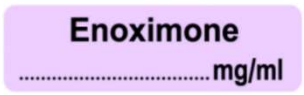

Inotropes
Increase cardiac output (heart rate and contractility), some also increase peripheral vascular resistance.

Adrenaline
- Causes vaso**constriction** in the doses used clinically.
- Can be used peripherally (short term emergency use).
- Can be given as bolus, but outside of cardiac arrest only by people with experience.
- Comes in multiple different concentrations and preparations so be very careful.
- If someone asks you to give adrenaline bolus clarify the concentration and how much they want you to give.

Dobutamine
- Causes vaso**dilatation.**
- Must be used centrally.
- Used in cardiogenic shock.

Dopamine
- Causes vaso**constriction.**
- Not commonly used in adult intensive care – more commonly used in paediatric setting.

Isoprenaline
- Can be used peripherally or centrally in treatment of severe bradycardia.
- Maybe useful as a bridge to pacing.

Milrinone and Enoximone
- These are intoropes which also cause vasodilation (inodilators).
- These drugs are usually started following the advice of a consultant.

6.0 Fluids and feeding

6.1 Intravenous fluids on ICU

A thorough assessment of the patient should be made to help guide fluid management, although fluid balance assessment in critical care patients are often challenging.

A key part of high-quality critical care nursing is the documentation of all fluid input and all fluid output. The former minus the latter gives the fluid balance. This should be monitored throughout the day, with a daily balance noted at the end of 24 hours. It is also key to monitor the cumulative balance from consecutive days.

A few general points should be considered when prescribing intravenous (IV) fluid on ICU:

- Most ICU patients do not require background IV fluids (ie 8 hourly bags) as most have some form of enteral or parenteral feed synchronously running.
- Whenever possible, patients should get their fluid requirements from their enteral feed.
- IV drug infusions and regular medications provide a significant fluid load.
- When ICU patients are fluid deplete, it is more common to administer a fluid bolus.
- Critically unwell patients have different volume goals over the course of the ICU dependent on their illness:
    - The initial phase often requires fluid resuscitation and a positive fluid balance.
    - Towards the end of their illness, patients often go through a deresuscitation phase, where excess fluid and salt is excreted. There may be a role in supporting this with diuretics.
- Different fluids contain different electrolytes!
    - The choice of fluid depends on what you want to achieve.
    - Fluids with higher sodium content have higher osmolalities and may be more appropriate in patients with neurological injury as this limits brain oedema for example.
    - Consider how a fluid will behave and the implication on that on the patient's illness.
- Colloids are now virtually never used due to their link to renal injury.
- Blood products may be appropriate to use:
    - Human Albumin Solution (20% or 4.5%) may be used under senior guidance, but without good evidence.
    - The blood transfusion threshold is usually 70mg/dL, but is 90-100mg/dL in patients with cardiac or neurological ischaemia.

6.2 Feeding on ICU

Enteral feeding should be established as soon as appropriate in ICU, preferably via a nasogastric tube. However, it is rarely an acute life-saving treatment, and therefore should only be commenced when safe to do so.

Enteral feed:

- Should be prescribed and increased as per unit protocol.
- Bedside nurses will record 'aspirates' or 'residual volumes' as they aspirate the NG tube every 4 hours, and this will guide how well a patient is absorbing their feed.
- Many critically unwell patients will require insulin (usually given as a variable rate intravenous infusion of actrapid) to maintain a 'normal' blood glucose of 5-10mmol/L.
- There is lots of potential for error when giving actrapid (as a sedated patient cannot complain of being unwell or hypoglycaemic if there is an error in administration), so check the unit protocol carefully before acting on erroneous blood glucose readings.

If NG feeding is not established, options include:

- Prokinetics: IV metoclopramide (1st line), IV erythromycin (2nd line).
- Insertion of NJ tube.
- Parenteral nutrition (given under senior guidance).

Gastric-protection should be considered for patients who do not have full gastric feeding established. Different units have differing approaches to this, so check your unit's protocol. Options include:

- Proton pump inhibitors: IV or enteral depending on absorption. These reduce gastric bleeding but do not improve survival.
- 'Trophic' feeding: 5-10mls/hr NG.

Consider nutritional supplements where indicated:

- Vitamins, particularly in high dose if risk of Wernicke's encephalopathy.
- There is not evidence for routine administration of vitamins in sepsis.

Parenteral feeding:

- Usually only indicated if unable to establish enteral feed by day 7.
- Should continue to try to feed enterally if appropriate, as this will protect the lining of the GI tract and will give an indication of when the patient is able to absorb enterally.
- Prescribing and alterations led by ICU dietician.
- Must be given via an *unused* port of the central line or via a new PIC line.

Nasogastric tubes on ICU

There is significant morbidity and mortality associated with the delivery of feed through incorrect placement of NG tubes in ICU patients.

The tubes may be sited incorrectly on initial placement or can become displaced.

Please ensure:

- You do the local and regional e-learning that is required to make you competent in the placement and interpretation of NG tube position.
- You familiarize yourself with your unit's policy on correctly identifying NG position.
- You read the NPSA guidance available here.
- You **ALWAYS** use a systematic approach to check the position of an NG tube on CXR, and document your findings clearly in the patient's notes.

7.0 Infection control

General infection control measures used on ICU

- Aprons and gloves required when entering patient's bedspace **at all times.**
- Don't use your own stethoscope – each bed should have it's own.
- Follow care bundles (see below) and LocSSIPs.
- Everyone should be bare below the elbows- no watches.
- Decontaminate hands before and after patient care. Remember, *C. Difficile* needs soap and water and not hand gel.

Local guidelines and microbiology services

- Most ICUs will have a daily microbiology ward round to discuss therapy and escalation options.
- In the absence of such advice, always follow local microbiological guidelines when commencing antimicrobial therapy.
- Each unit will have their own protocols on those related to antibiotic infusions, antibiotic dose monitoring and (where available) the use of Procalcitonin (PCT).

Care bundles

There is much effort to avoid iatrogenic or hospital acquired infections on ICU, because patients are not only more vulnerable to infection, but any acquired infection may be more significant for a given patient.

Some examples of measures or bundles designed to minimise the risk of infection include:

- Airway: use of tracheal tubes with subglottic suction ports, and cuffs designed to minimize microaspiration.
- Breathing: sitting up 30-45^{o}, regular oral decontamination with 1% chlorhexidine.
- Circulation: central lines which are antibiotic or chemically impregnated to reduce the risk of infection, chlorhexidine impregnated central line dressings, aseptic technique when sampling from lines.
- Daily chlorhexidine body scrub.

8.0 VTE prophylaxis

Critically ill patients are at high risk of venous thromboembolism (VTE) due to illness and immobility, and appropriate prophylaxis should be considered for every patient, every day.

A thromboprophylaxis decision that is appropriate for one patient on a given day may not be appropriate for the same patient on another day, with changes such as falling platelets, bleeding or impaired renal function.

General points to consider:

- Standard chemical VTE prophylaxis with low molecular weight heparin (e.g. dalteparin or clexane) is often appropriate if renal function is acceptable and there is no risk of precipitating bleeding or worsening the consequences of bleeding (e.g. in intracranial hemorrhage).
- This is often combined with a physical thromboprophylaxis such as stockings or calf compressors.
- VTE prophylaxis should be prescribed according to local guidelines, with consideration of patient weight, renal function, bleeding tendency and risk from bleeding.
- Consider timing of doses around planned interventions e.g. tracheostomy.
- Ensure appropriate gastric protection (see section 6.2).

Drugs used:

- Subcutaneous low molecular weight heparin is often the first line agent if renal function is acceptable (usually eGFR >25).
- In impaired renal function, and particularly for patients on renal replacement therapy, subcutaneous unfractionated heparin is usually used.
- IV heparin is commonly used if full anticoagulation is required and the desire to reverse it rapidly is required. Monitoring should follow local guidelines (e.g. antiXa levels).

9.0 Renal replacement therapy

9.1 Introduction - what is expected of you?

A recurring theme in our feedback has been the omission of the topic of renal replacement therapy (RRT) from the course. Many doctors who are new to ICU haven't encountered it before, and it can be intimidating. It is also a big topic to cover, which is why we haven't incorporated it in the course itself, but have included a short chapter here to introduce the main concepts.

One of the first things to appreciate is that you won't be managing RRT alone. Decisions about starting, adjusting or discontinuing RRT will be largely consultant-led. You might have to do some trouble shooting, and the senior nurses are often an indispensable source of wisdom for that. You will however be responsible for prescribing the different components of the therapy, however this is highly protocolised and described in local guidelines.

Here, we're aiming to provide you with an appreciation of the indications for RRT, how it works (in simple terms) and how to manage some commonly-occurring issues.

Figure 1 - Prismaflex RRT system, adapted from Baxter Prismaflex product information, https://www.baxter.com/healthcare-professionals/critical-care/prismaflex-system-critical-care, accessed 25/1/22

9.2 Definitions and principles

RRT encompasses several treatment modalities, all supporting the impaired kidney. On ICU we are most commonly supporting patients with acute kidney injury (AKI) and we use different modalities to those provided to patients with chronic kidney disease (CKD) in renal units.

Continuous vs intermittent

ICUs tend to use continuous RRT. Renal units tend to use intermittent haemodialysis (IHD) for patients with CKD on an out-patient basis.

IHD can involve blood flow rates of up to 500mL/min. This is a very efficient way of removing waste solutes such as urea. A single treatment can be completed in 3-4 hours. However these high flow rates can cause significant haemodynamic shifts, which are poorly tolerated in unwell patients, and may even result in cardiovascular collapse. As a result, continuous modalities were developed, using blood flow rates from 80-250mL/min. This is less efficient but more cardiovascularly stable. It does, however, rely on continuous (i.e. uninterrupted) therapy which may be challenging to deliver given the need for scans, trips to theatre etc.

Arterio-venous vs veno-venous

Early machines used the patient's arterial blood pressure to drive blood out through an arterial cannula, round the system and back into a venous cannula. Arterial access cannulae needed to be big and were associated with arterial complications. In addition, shocked patients often had insufficient blood pressure to drive the system effectively.

Modern machines use a single venous cannula with two lumens and a blood pump to drive the blood round the circuit and back to the patient. This is better tolerated and is associated with fewer complications.

Dialysis vs filtration and the principles of RRT

Dialysis describes the process of diffusion across a semi-permeable membrane, such that the blood (on one side) equilibrates with the dialysis fluid (on the other side). This gradient is maintained by a counter-current mechanism, where blood and the dialysis fluid or dialysate (a carefully balanced and buffered solution of electrolytes in purified water) are infused in opposite directions on either side of the membrane (see Figure 2 and 3).

Filtration describes the process of fluid passing through the semipermeable membrane due to convective forces and differences in hydrostatic pressure on either side of the membrane. Passage of fluid will drag solutes with it (this is known as solute drag). This causes "ultrafiltration" of the plasma component of the blood, which is forced through the filter membrane under pressure and carries solute particles with it by "solute drag" (see Figure. 3). If a high proportion of the blood's fluid component is ultrafiltered, the patient will require replacement fluid to prevent intravascular depletion. This can be introduced to the circuit either before or after the filter.

Dependent on the RRT machine and the settings selected, ICUs may use one, or a combination of dialysis or filtration. Therapeutic options include:

- CVVHF - continuous veno-venous haemofiltration.
- CVVHD - continuous veno-venous haemodialysis.
- CVVHDF - continuous veno-venous haemodiafiltration.

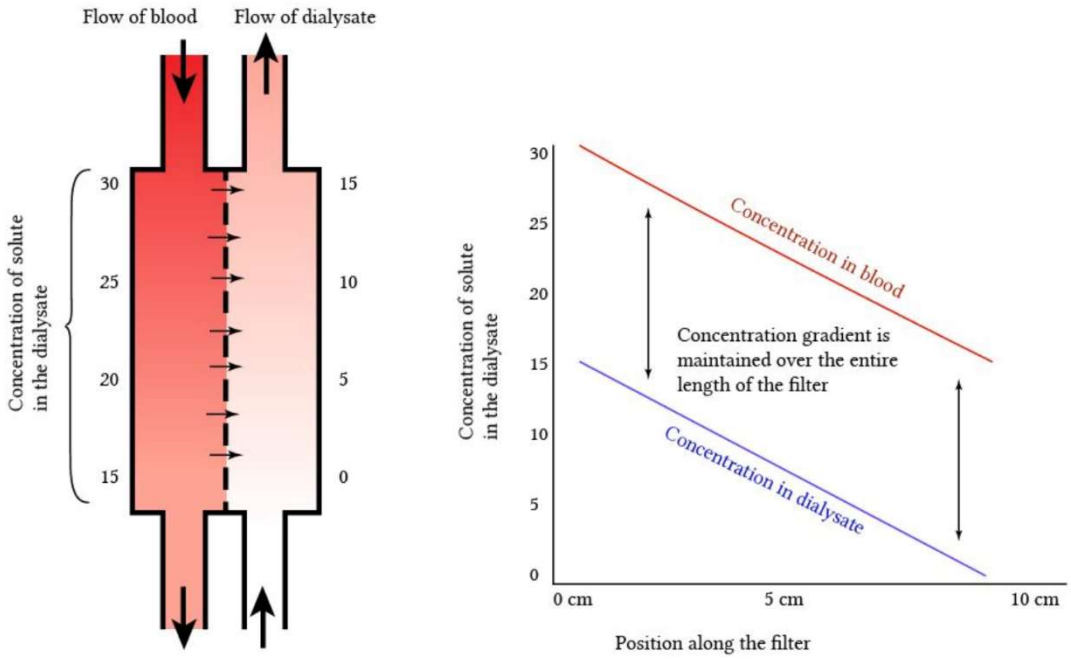

Figure 2 - schematic of dialysis - diffusion of solute across semi-permeable membrane, with countercurrent dialysate flow maintaining constant diffusion gradient across whole length of filter.
Adapted from derangedphysiology.com, accessed 25/1/22

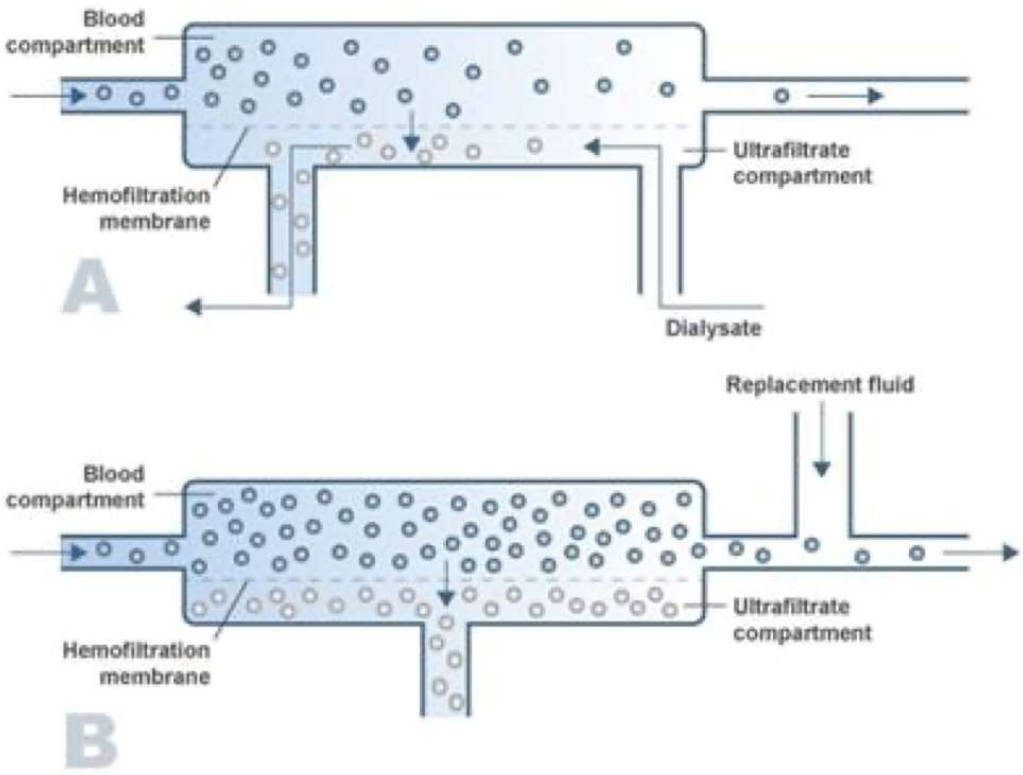

Figure. 3 - Schematic comparison of haemodialysis (A) and haemofiltration (B) across semi-permeable membrane. In A, countercurrent dialysate flow generates diffusion gradient. In B, blood is ultrafiltered through the membrane under pressure.
Adapted from https://www.health.qld.gov.au/__data/assets/pdf_file/0013/1020604/CCRM-Dialysis-Did-you-

Indications

Indications for urgent RRT can be recalled with the mnemonic AEIOU. RRT is indicated where there has been no response to initial medical therapy, unless initiation of medical therapy is futile (e.g. in a patient with no renal function who is totally dependent on dialysis):

A	Acidosis
E	Electrolyte disturbance, particularly hyperkalaemia
I	Intoxication with dialysable toxins
O	Fluid overload
U	Uraemia with complications, e.g. pericarditis, encephalopathy

The dialysable toxins have their own mnemonic: I STUMBLE:

I	Isopropyl alcohol
S	Salicylates
T	Theophylline
U	Urea
M	Methanol
B	Barbiturates
L	Lithium
E	Ethylene glycol

9.3 Equipment

You and the nurses will need:

- Vascular access device - large-bore, dual-lumen catheter in central vein (a vascath).
- A filter machine.
- A filter set and associated tubing - biocompatible to minimise immune activation.
- Replacement fluid and/or dialysate.
- Anticoagulant - see section below.

9.4 Anticoagulation

In almost all cases, some form of anticoagulation is needed to prevent activation of the coagulation cascade and clotting of the filter. The only exception is in patients who are auto-anticoagulated (e.g. severe coagulopathy).

Previously, unfractionated heparin was commonly used, but this has been largely superseded by trisodium citrate. Citrate is a calcium chelator (calcium being an essential cofactor in the clotting cascade) and is added to the patient's blood as it leaves the patient or enters the filter circuit. Over half of the citrate-calcium complexes are removed by the filter. Free calcium is then added back to the blood as it leaves the circuit or enters the patient, thereby restoring coagulation. The citrate-calcium complexes returned to the patient are cleaved and the citrate is rapidly metabolized to bicarbonate, mostly in the liver. In this way, only the circuit is anticoagulated, with very minimal effects on the patient themselves. This is extremely helpful particularly in patients at risk of bleeding.

Citrate use is complex and potentially dangerous if not done properly, so is managed with a rigid protocol and close monitoring of blood gases and ionized calcium.

Some very unwell patients, particularly those in decompensated liver failure can't metabolize citrate, so might be managed with heparin or epoprostenol (flolan) instead. The downside of this is that the patient will be fully anticoagulated.

9.5 Dosing

Dosage of RRT is given as the ultrafiltration volume produced per hour. There is some evidence to suggest that dosages of 25-35mL/kg/hr are optimal. In a 70kg patient this works out at 1750-2450mL/hr. Some units will have a "standard" and an "enhanced" protocol; the choice of which is dependent on how derranged the patient's physiology is.

9.6 Complications

These can be split into complications of the access device, which are the same as those for any central line (see section 3.2f), and complications of the therapy itself, which include:

- Haemodynamic instability- due to fluid shifts. Often responds to a fluid bolus in the first instance, or a small increase in vasopressor.
- Bleeding - less common with citrate than with heparin, but can cause significant blood loss. Manage as for any major haemorrhage.
- The filter can clot despite anticoagulation. If a filter clots without the blood being returned to the patient, the 250mL or so in the circuit will be lost. If repeated, anaemia will result. Can often be predicted by rising transmembrane pressure (TMP - pressure across the filter membrane). If this occurs, consider returning the blood to the patient and abandoning the treatment attempt before blood is lost in this way.
- The filter can clag. This refers to a decrease in efficiency of the semipermeable membrane as it becomes coated in proteinaceous debris. If this occurs, less of the citrate-calcium complexes are dialysed, so more citrate is introduced into the body. This may manifest as alkalosis and hypernatraemia.
- Low phosphate (unless present in dialysate) and low magnesium. Citrate also binds magnesium, but this is less significant than calcium binding.
- Metabolic/acid-base abnormalities relating to replacement/dialysate fluid or citrate use - beyond the scope of this chapter! See your local RRT protocol for details.
- Rapid electrolyte changes. Beware that sodium will correct quickly as the patient equilibrates with the dialysate. This may be dangerous if the patient in hyponatraemic- most unit protocols have a way of managing this, so consult the unit protocol carefully in the context of hyponatraemia.

9.7 Summary

This chapter has given you the basics of RRT. You aren't expected to know the minutiae of it at this stage, so ask your senior colleagues and the nurses and consult your unit protocol if in doubt.

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