Ventilation for Acute Hypoxic Respiratory Failure in Critical Care

**Aim:** To provide a Standard Operating Procedure (SOP) for the early stabilisation of acute hypoxic respiratory failure in Critical Care patients.

### Scope

**Inclusion:** Adult Critical Care patients with hypoxic respiratory failure due to lung disease. As well as patients diagnosed with ARDS, this applies to patients who do not meet all criteria in the Berlin definition for ARDS.

**Exclusion:** Patients whose primary problem is bronchospasm, heart failure, fluid overload or pulmonary embolism.

### Key Principles

**Do the simple things well**
Maintain attention to detail, ensure plans are followed and avoid errors.

**Follow a stepwise approach**
Progress through this SOP, starting with the most important and evidence-based measures before trying others.

**Balance the risks of organ support**
Using unsafe ventilator settings to achieve “normal” blood gases can be more harmful than tolerating moderate hypercarbia / hypoxaemia.

**Minimise risks of cross-infection**
Not all measures in this SOP may be practical or safe in the context of transmissible infections. Follow Infection Control guidance for your specific circumstances to prioritise the safety of staff and other patients.
Phases of care

**Early Stabilisation**
- May take a few hours or one to two days.
- Aim to achieve a safe & stable level of respiratory support with acceptable physiology.

**Priorities**
- Adequate oxygenation to avoid end-organ damage
- Adequate CO2 clearance to avoid problematic acidaemia
- Minimise lung injury from excessive tidal volumes or airway pressures

**Continued Support**
- Maintaining organ support while managing underlying disease.
- Not the focus of this SOP but similar principles apply.

**Priorities**
- Limiting acquired muscle weakness by using spontaneous mode where possible (eg pressure support)
- Optimising all-round critical care organ support.

**Weaning**
- Reducing support and moving towards extubation.
- Beyond the scope of this SOP.

**Priorities**
- Progressively increasing the proportion of breathing work done by the patient.

**Strength of Recommendations**

This SOP is intended as a practical approach, taking into account the level of evidence available, the likely risks of each intervention, and the practicalities of delivering care in a stepwise manner.

Recommendations are given strongly or weakly, in favor or against, each intervention. Where available, the level of supporting evidence is stated.

For a more detailed review of the evidence, see FICM/ICS Guidelines on the Management of Acute Respiratory Distress Syndrome (July 2018)
Step 1: Lung Protective Ventilation
Standard practice for all acute hypoxic respiratory failure

A: Deep sedation and muscle relaxation

- Begin with deep sedation and muscle relaxation while trying to achieve stability, using atracurium infusion if not improving quickly. *(Strong recommendation, see Appendix A for method)*

- Continue deep sedation and atracurium infusion for further 24-48hrs if struggling to achieve safe parameters on ventilator (see below) or if persistent problems with ventilator synchrony *(weak recommendation, weak evidence)*

B: Limit tidal volume to 6ml/kg IBW

- Calculate ideal body weight based on known height, or estimate height using ulnar length. *(See Appendix B for chart)*

  Male IBW (kg) = 50 + 2.3 x ((height cm/2.54)-60)

  Female IBW (kg) = 45.5 + 2.3 x ((height cm/2.54)-60)

- Set tidal volume to 6ml/kg IBW using mandatory mode: PRVC on Servo® ventilator. *(Strong recommendation, moderate evidence)*

C: Higher levels of PEEP, titrated to patient

- Use higher levels of PEEP in patients with higher requirements for FiO₂

- Titrate to effect. Too little will encourage atelectasis while too much can cause overdistention, reduce compliance, and cause hypotension.

- Typical requirements in severe ARDS may be 15 cmH₂O or more. *(Strong recommendation, weak evidence)*

<table>
<thead>
<tr>
<th>FiO₂ Requirement:</th>
<th>0.4</th>
<th>0.6</th>
<th>0.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical starting PEEP (cmH₂O)</td>
<td>5-14</td>
<td>10-20</td>
<td>14-22</td>
</tr>
</tbody>
</table>
D: Tolerate higher PaCO$_2$ to keep plateau airway pressures under 30 cmH$_2$O$^{(1)}$

- Accept hypercapnia if target arterial pH over 7.25 (or over 7.20 if need for ventilation/lung protection outweighs other organ failures)
- Keep plateau (and, ideally, peak) airway pressures below 30 cmH$_2$O
  (Strong recommendation, moderate evidence)

E: Tolerate moderate hypoxaemia$^{(4)}$

- Tolerate SpO$_2$ as low as 90% or pO$_2$ 8-9 kPa even if no chronic lung disease, in preference to sustained high FiO$_2$ requirements (over 50%)
  (Strong recommendation, moderate evidence)

F: Conservative fluid management$^{(1)}$

- Aim for neutral-to-negative fluid balance if not excessively detrimental to other organ systems
- Monitor effect on cardiovascular and renal system. It may be better to accept a moderately higher requirement for vasopressor if this permits improved oxygenation in severe hypoxaemia.
- Consider fluid restriction or diuretics to achieve fluid balance
  (Weak recommendation, poor evidence)

G: Optimise management of reversible causes

- Consider investigations and/or empirical treatment for drug-resistant infection, unrecognised heart failure, pulmonary embolus and other differential diagnoses.
Step 2: Additional Measures
Consider after addressing Step 1 measures

H: Prone ventilation may be helpful for all patients with severe ARDS\(^{(1)}\)

- If adequate control of arterial pH and PaO\(_2\) cannot be achieved with Step 1 measures, consider prone ventilation.
- If stability is achieved with Step 1 measures, but requiring FiO\(_2\) over 0.6 and PaO\(_2\):FiO\(_2\) ratio is less than 20kPa, consider prone ventilation.
- Before commencing prone ventilation, ensure other urgent interventions and investigations are completed (eg CVC, Bronchoscopy)
- Keep prone for around 16 hours at a time if tolerated.
- See Appendix C for practical guide to prone ventilation
  (*Strong recommendation, moderate evidence*)

I: Consider lung recruitment manoeuvres\(^{(1)}\)

- Only likely to be beneficial in patients with reversible atelectasis
- Avoid disrupting the ventilator circuit: If attempted, use the ventilator (eg. with inspiratory hold function), rather than by hand ventilation.
- Beware causing cardiovascular compromise eg. if hypovolaemic
- If ineffective, do not repeat.

J: Consider need for bronchoscopy

- Only likely to be beneficial in patients with lobar collapse due to mucous plugging.
- Expect de-recruitment and short-term worsening of atelectasis, even in patients in whom mucous plugging can be treated.
- This is a high risk procedure for aerosolisation of pathogens
Step 3: ECMO Referral
Consider early, while working through Step 2 measures

K: Consider ECMO Referral\(^{(1)}\)

- If unable to achieve acceptable PaO2 and pH with safe settings on the ventilator despite addressing measures within Step 1
- **Consider and discuss with tertiary centre early**, based on senior consensus discussion.
- **Criteria include:**
  - Potentially reversible acute lung disease
  - Murray Score of 3 or more:

**Murray Score**

<table>
<thead>
<tr>
<th>Points</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>P/F ratio (kPa)</td>
<td>≥40</td>
<td>30-39.9</td>
<td>23.3- 29.9</td>
<td>13.3- 23.2</td>
<td>&lt;13.3</td>
</tr>
<tr>
<td>PEEP (cmH(_2)O)</td>
<td>≤5</td>
<td>6-8</td>
<td>9-11</td>
<td>11-14</td>
<td>≥15</td>
</tr>
<tr>
<td>Static compliance (ml/cmH(_2)O)</td>
<td>≥80</td>
<td>60-79</td>
<td>40-59</td>
<td>20-39</td>
<td>≤19</td>
</tr>
<tr>
<td>CXR quadrants infiltrated</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Murray Score = Total Points / 4
Compliance = \( \frac{\text{Vt}(\text{ml})}{(\text{Pplat} - \text{PEEP})} \)
Step 4: Consider Unproven Therapies
These may do more harm than good - only consider after addressing other measures and exploring possibility of ECMO.

L: Unproven therapies include\(^{(1)}\)

- **Extra-corporeal CO2 removal** (eg Novalung iLA)
- **Inhaled vasodilators** (weak evidence suggests may be harmful)
- **High frequency oscillation** (moderate evidence suggests harmful)

References & Comments


   2018 FICM/ICS Guidelines on management of ARDS available at
   [https://www.ficm.ac.uk/sites/default/files/ficm_ics_ards_guideline_-_july_2018.pdf](https://www.ficm.ac.uk/sites/default/files/ficm_ics_ards_guideline_-_july_2018.pdf)


   **ROSE Trial, published after the 2018 FICM/ICS Guidelines, further weakening the evidence for routine use of 48-hour atracurium infusion in severe ARDS (no difference in outcomes compared with “usual practice” of light sedation)**


   **ARDSnet trial from which the figures for the suggested PEEP values are taken. The range given in this SOP is a combination of the “lower PEEP” and “higher PEEP” tables, to illustrated the range of values that may be needed.**


   **ICU-ROX Trial, published after the 2018 FICM/ICS Guidelines, showing no significant difference in outcomes between conservative oxygen therapy (target SpO2 90-97%) and usual care.**

Appendix A
Neuromuscular Blockade in Critical Care

Consider continuous neuromuscular blocking agents (NMBAs) for patients with:
- Severe respiratory failure requiring advanced ventilation strategies (see Ventilation SOP)
- Severe head injury & raised intracranial pressure
- Shivering during targeted temperature management
- Uncontrollable muscle spasm or rigidity

Discuss with ICU Consultant, check no contraindications, and confirm choice of drug

Ensure deeply sedated (eg RASS -5) then test baseline train-of-four (TOF) response.
Note the current required: should be minimum needed for maximum response.

Give IV loading dose: Atracurium 0.3 - 0.6 mg/kg over 1 minute (1st line in Critical Care)
Start IV infusion: Atracurium 0.3 - 0.6 mg/kg/hr (1st line in Critical Care)

Check TOF every 30 minutes until infusion rate has been stable for two tests.
When infusion rate has been stable for two tests, check TOF routinely every four hours.

If more than two twitches seen or felt:
- Increase Atracurium infusion rate by 10%
- Consider bolus dose (discuss with doctor)
- Repeat train-of-four monitoring in 30 minutes

If fewer than two twitches seen or felt:
- Reduce Atracurium infusion rate by 10%
- Repeat train-of-four monitoring in 30 minutes

Electrode placement for ulnar nerve stimulation - first choice site for train-of-four monitoring.
Place negative (black) electrode closest to hand.

Remember
- Daily break in NMBA if condition allows
- Eye and pressure area care
- Passive physiotherapy
- Adequate DVT prophylaxis
Appendix B

Ideal Body Weight Calculations

If height is known, use this for IBW calculations.
If height is not known, use ulna length to estimate height.

Estimating height from ulna length\(^5\)
Measure between the point of the elbow (olecranon process) and the midpoint of the prominent bone of the wrist (styloid process), on the left side if possible.

<table>
<thead>
<tr>
<th>Height (ft)</th>
<th>5'</th>
<th>5'1&quot;</th>
<th>5'2&quot;</th>
<th>5'3&quot;</th>
<th>5'4&quot;</th>
<th>5'5&quot;</th>
<th>5'6&quot;</th>
<th>5'7&quot;</th>
<th>5'8&quot;</th>
<th>5'9&quot;</th>
<th>5'10&quot;</th>
<th>5'11&quot;</th>
<th>6'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (m)</td>
<td>1.52</td>
<td>1.55</td>
<td>1.57</td>
<td>1.60</td>
<td>1.63</td>
<td>1.65</td>
<td>1.68</td>
<td>1.70</td>
<td>1.73</td>
<td>1.75</td>
<td>1.78</td>
<td>1.80</td>
<td>1.83</td>
</tr>
<tr>
<td>IBW Male (kg)</td>
<td>50</td>
<td>52</td>
<td>55</td>
<td>57</td>
<td>59</td>
<td>61</td>
<td>64</td>
<td>66</td>
<td>68</td>
<td>71</td>
<td>73</td>
<td>75</td>
<td>78</td>
</tr>
<tr>
<td>IBW Female (kg)</td>
<td>46</td>
<td>48</td>
<td>50</td>
<td>52</td>
<td>55</td>
<td>57</td>
<td>59</td>
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<td>64</td>
<td>66</td>
<td>68</td>
<td>71</td>
<td>73</td>
</tr>
</tbody>
</table>
Appendix C
Prone Ventilation in Critical Care

Indications
Consider proning early when adequate oxygenation can not be achieved within lung protective ventilation parameters (See Ventilation SOP). Typical criteria include:

- Ventilator settings optimised, paralysed and recruitment manoeuvres attempted
- Requiring FiO2 over 0.65 to keep PaO2 over 8kPa
- Unable to keep peak airway pressure below 30cmH2O

Potential Contraindications

Absolute contraindications include:
- Open abdomen
- Unstable cervical spine

Relative contraindications include:
- Cardiovascular instability
- Head injury with raised ICP
- Eye or facial injury
- Thoraco-lumbar spinal injury
- Pelvic fracture
- Recent abdominal surgery
- Gross ascites or obesity
- Pregnancy in 2nd or 3rd trimester
- Intra-aortic balloon pump

Pre-Turn Considerations

- Ensure sufficient staff available:
  - 1 doctor with intubation skills
  - 4 additional nurses or doctors
- Assess pressure areas, ensure suitable mattress & consider extra padding (eg Aderma cups)
- Eye care: clean & lubricate with simple ointment (eg Lubitears), then close with tape.
- Perform standard DCCQ mouth care.
- Check grade of intubation, current length of ETT at teeth, and suitable ETT securing (not Anker Fast or Elastoplast)
- Ensure deep sedation and adequate muscle relaxation.
- Aspirate NGT and pause feed while turning
- Disconnect non-essential IV lines and luer lock, for re-connection immediately following the turn (take great care with sterility)
- Ensure there is adequate length of IV tubing for essential infusions while turning.
- Remove ECG electrodes from anterior chest wall and reposition on back/sides.
- Try to re-position chest drain sets without lifting above the patient. Any temporary clamping of chest drains for turning should only be done by a senior doctor.

Beware proning too soon after admission to ICU. First try to give other measures a chance to work, carry out essential transfers, and ensure all necessary lines are in and working.
**Maintaining in the Prone Position**

- Aim to keep in prone position for 16-18 hours at a time.¹
- As long as proning is still required, aim to keep prone for at least 75% of the time (eg 18/24 hours).¹
- Vary the prone position regularly, eg rotating through positions A, B, C & D every 1-2 hours.
- After rotating through A-D, repeat with the opposite side of the body (ie right hand up, instead of left).
- Watch carefully for new pressure areas on the front of the body and take special care to avoid pressure on the eyes.
- At the end of each prone session, re-assess the need for further proning.

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**Turning to the Prone Position**

"Cornish Pasty" technique

1. Complete Team Brief (plan procedure, safety checks and establish team leader/airway)
2. Place 1 slide sheet and 1 sheet underneath patient
3. Place 1 pillow on chest and 1 on pelvis (fig. A)
4. Place patient’s hands under their buttocks
5. Place 1 sheet and 1 slide sheet of top of the patient
6. Ensure pressure areas are protected (genitals, breasts, knees etc)
7. Arrange all lines above the waist upwards
8. Arrange all lines below the waist downwards
9. Roll all sheets together on each side of the patient (fig. B)
10. Slide patient across to the edge of the bed
11. Roll patient into side lying position and recheck airway, lines and vital signs (fig. C)
12. Continue rolling patient into prone position
13. Remove slide sheets and position head and arms in “swimming” position (fig. D)
14. Re-connect all lines, ensuring sterility has been strictly preserved
15. Re-start feed, ensuring NGT has not been dislodged

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¹ Assumes patient is in acute critical care unit with constant monitoring and intervention.
“Cornish Pasty” Technique - Images

Fig A: placing one pillow on chest and one pillow on pelvis

Fig B: rolling all sheets together on each side of the patient

Fig C: rolling patient into side lying position and rechecking airway, lines and vital signs

Fig D: removing slide sheets and positioning head and arms in “swimming” position