Specialty guides for patient management during the coronavirus pandemic

Clinical guide for use of anaesthetic machines to provide continuous invasive ventilatory support for adult patients during the coronavirus pandemic

28 April 2020, Version 1

Introduction

The use of anaesthetic machines as ventilation stations for continuous support of COVID-19 patients as part of surge and super-surge capacity is considered an off-label use. The MHRA recognises that use of anaesthetic machines in this way may be required under current pandemic conditions. This guidance has recently been requested in order to support clinicians (critical care physicians, anaesthetists, nurses and other support staff) in the safe use of anaesthetic machines for this purpose. As with all medical devices, please refer to the manufacturer’s guidance for information about the safe use of specific machines.

Summary

- Anaesthetic machines should ideally be reserved for patients who need ventilating with the lowest critical care acuity scores and whose lung compliance makes them easier to ventilate.
- It may be necessary to move patients from an anaesthetic machine ventilator to a conventional critical care ventilator if the patient’s lung compliance deteriorates.
- Anaesthetic machines are designed to be restarted and self-tested every 24 hours to ensure proper calibration, accuracy and performance. An interval of up to 72 hours is permitted during the pandemic according to guidance from most manufactures.
Pre-use

- The machine needs to be configured for long-term use with attention to gas supplies and removal of nitrous oxide.
- Antiviral filters must be used to protect staff and to prevent contamination of the machine.

In use

- Oxygen concentrations in the circuit must be monitored as well as FiO2, FiCO2 and EtCO2 in all patients.
- The default alarm limits are not suitable for caring for critically ill patients and will need adjustment.
- Fresh gas flows should replace patient oxygen consumption and losses due to leaks and gas sampling i.e. at least minute volume x FiO2 + 1 litre per minute to avoid rebreathing and generation of excess humidity.
- An increase in the fresh gas flow every four hours is recommended to help dry the internal components of the machine.
- Regular inspection of the circuit for accumulation of water or collapse of the reservoir bag/bellows.

Differences between intensive care unit (ICU) ventilators and anaesthetic machines

Anaesthetic machines differ from ICU ventilators in the following important ways:

- Ability to alter fresh gas flows and degree of rebreathing.
- Integrated volatile anaesthetic agent delivery system.
- Soda lime absorption of CO2.
- Potential to deliver hypoxic mixture at low flows.
- Absence of a pressure relief valve to limit Pmax.
- Ability to deliver gas through more than one outlet, for example, a common gas outlet.
- Lack of leak compensation, for example, for inline suction compensation.
Potential issues with COVID-19 ventilation using anaesthetic machines

- **Increasing resistance to gas flow** due to saturation of filters with water
  - \(\text{CO}_2\) absorbers produce water vapour
  - **resistance to expiratory flow** is an early sign with prolonged expiratory phase on the flow tracing, with slurring of the expiratory capnograph
  - **increased airway pressure** is a late sign
  - MHRA Patient safety alert:
- **Collection of water in dependant areas of the breathing system**
  - pressure/flow oscillations may be **sensed as patient inspiratory effort**
  - if total respiratory rate > set respiratory rate this should be considered.
- **ETT cuff leak with lack of leak compensation**
  - loss of inspiratory pressure end expiratory pressure
  - bellows will fall and the reservoir bag will progressively deflate (loss of pressure)
  - risk of aerosolization of tracheal and pharyngeal secretions
  - noticeably **exhaled tidal volume < inhaled tidal volume**
  - the flow-volume loop does not close.
- **Residual inhalational agents** with risk of triggering malignant hyperthermia if the machine is not appropriately flushed.
- **Potential for machines equipped with monitoring only modes or cardiac bypass mode** allowing apnoea without alarming.
- **A ‘backup mode’ of ventilation is not always present** with the modes of ventilation found on anaesthetic machines. This could result in prolonged apnoea if not recognised.

Pre-use

Preparation of an anaesthetic machine for long-term ventilation

- **Pre-emptively in planning phase consider changing the drive gas** from oxygen to air if the anaesthesia machine contains a bellows – see Appendix 7 - Oxygen consumption/conservation.
- **Remove:**
  - \(\text{N}_2\text{O}\) cylinders and pipeline supplies should be disconnected (issues with prolonged use of \(\text{N}_2\text{O}\) on cellular processes) and some machines, for example,
Dräger, Zeus Perseus, Primus need to be reconfigured in line with manufacturer’s instructions.

- Machine usage without N2O must be configured in the system configuration settings

- Machines should be regularly powered on and off to allow P.O.S.T. and machine checks.

- Connect:
  - The machines should preferably be connected to pipeline supplies of oxygen and air and if not available use large G/H cylinders with backup oxygen and air cylinders.
  - Machines will differ as to how they handle not being connect to an AGSS (anaesthetic gas scavenging system), check the manufactures guidance.

- Filter configuration is important in order to protect staff, the machine from contamination and other patients from cross infection.

- Turn off any mute apnoea alarms or cardiac bypass modes, if present.

- Ensure alternative means of ventilation nearby, for example, self-inflating bag.

- Check and set individualised alarms, for example, FiO₂ (default alarms are not appropriate for critical care patients – see monitoring section).

- Set appropriate fresh gas flows - at least Minute Volume x FiO₂ + 1 litre per minute.

## Setup prior to use

### Humidification

- Active humidification of an anaesthetic circuit must not be used.

- Use passive humidification with an HME or HMEF where possible.
  - If using an HME then viral filters will still be required.
  - Dual heated breathing circuits must not be used.

### Filters, HMEs and HMEFs

- Filter configuration is important in order to protect staff, the machine from contamination and other patients from cross infection.
  - Always use a viral/bacterial filter on the expiratory port of the machine.
  - If a HMEF or viral filter is used at the patient Y-piece than additional filtration is not required at the inspiratory port.
  - If an HME is used at the patient Y-piece then ensure viral filtration is present on the inspiratory port.
– Use proximal gas sampling and ensure that gas is sampled from the device side of the filter to prevent contamination of the machine or unnecessary exposure of staff.

Further information is available on the Anesthesia Patient Safety Foundation website.

CO₂ absorber
• Need for changing is indicated by a colour change of the absorption material.
• Hourly checks of the colour are advised.
• A rising FiCO₂ or a 2/3 colour change should prompt a change of material.
• Total gas flows and the metabolic status of the patient will determine rate of use.

Considerations for ventilation of COVID-19 patients during use of anaesthetic machines

1. Oxygen - delivery to patient

Oxygen concentrations in the circuit need to be monitored
• The ability to change fresh gas flow and therefore the amount of rebreathing is one of the key features distinguishing an anaesthetic machine from an ICU ventilator.
• The FiO₂ will depend on the fresh gas flow and the amount of rebreathing.
• Rebreathing increases as fresh gas flow is reduced below minute ventilation.
• If FiO₂ is dependent on user set ratio of oxygen flow to air flowrates, ensure adequate FiO₂. Further information is available in Appendix 1: FiO₂ / L/min conversion rates.

2. Fresh gas flow rates
• Set the total gas flow of at least Minute Volume x FiO₂ + 1 litre per minute to avoid rebreathing and generation of excess humidity in the circuit and additionally resilience against system leakage.
• The minimum safe fresh gas flow replaces patient oxygen consumption and losses due to leaks and gas sampling, if a CO₂ absorber is being utilised.

3. Suctioning
• Use inline suctioning, closed suction devices.
• Suctioning causes the loss of inspiratory and end expiratory pressure.
Strategies to attenuate this effect:

- **Turn up oxygen fresh gas flow** to maximum aiming to increase FiO2 and patient oxygenation prior to suctioning and also to compensate for pressure loss in the circuit.
- Set the **APL valve to +15 cmH2O**.
- **Mute alarm** and switch to **manual ventilation**.
- **Turn on suction**.
- **Ventilate with bag** while colleague performs suctioning.
- **Switch ventilator back on**, unmute alarms and check ventilation.
- Check and readjust total fresh gas flows.

4. **Control of circuit humidity**

- **Periodic drainage of water** from the circuit and water traps will be required – an alternative means of ventilation may be required during drainage.
- Draining water from the circuit.
- Water from the circuit should be handled as **hazardous waste**.

5. **Self-test**

At least every 72 hours the self-test process should be undertaken to refresh the machine and prevent machine protective software driven shutdown using the sequence below:

- **Manually ventilate** the patient using appropriate back up breathing system.
- **Cycle the power** (turn on/off) at the same time as performing the self-test.
- Length of continuous use should be monitored if using anaesthetic machines for prolonged periods without performing self-testing.
- **Self-test check list** is included in the appendices.

6. **Monitoring**

- **FiO2, FiCO2 and EtCO2** must be monitored in all patients
- The **default alarm limits are not suitable** for caring for critically ill patients
  - Ensure the **high FiCO2 alarm** is set - it is disabled by default on some anaesthetic machines.
  - Set an appropriate **low FiO2 alarm**, **high/low MV** and **high/low EtCO2**.
  - Set upper limit of **pressure alarms** (note this does not limit pressure).
- **Ensure alarm volume levels** are suitable for the environment the machine is being deployed in.
- An **additional monitoring schedule** is included in the appendices.
7. Miscellaneous

- Before performing a sedation hold for patients on mandatory ventilation - check to see if the anaesthetic machine is in the correct mode to allow spontaneous breaths or switch to an alternative machine.

Turnaround between patients

- **Cycle the power** (turn on/off) before preparing for a new patient.
- **Perform a complete system self-test**, not just a leak test.
- **There should be no risk of contamination of the machine** if appropriate filter configuration has been used.
- **If there are concerns about contamination** of the machine, then follow the manufactures decontamination advice.
- **Discard disposable items** – breathing circuit, reservoir bag, patient masks, gas sampling tubing and filters.
- **Wipe all exposed services.**
- **Links to manufacture’s cleaning instructions are available on the Anesthesia Patient Safety Foundation website.**

### Appendix 1: FiO2 / L/min conversion rates

<table>
<thead>
<tr>
<th>Desired FiO2</th>
<th>Oxygen to Air Ratio</th>
<th>Oxygen flow for 10 L/min</th>
<th>Air flow for 10 L/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>21%</td>
<td>0 to 1</td>
<td>0.0</td>
<td>10.0</td>
</tr>
<tr>
<td>25%</td>
<td>0.06 to 1</td>
<td>0.6</td>
<td>9.4</td>
</tr>
<tr>
<td>30%</td>
<td>0.13 to 1</td>
<td>1.2</td>
<td>8.8</td>
</tr>
<tr>
<td>35%</td>
<td>0.21 to 1</td>
<td>1.8</td>
<td>8.2</td>
</tr>
<tr>
<td>40%</td>
<td>0.31 to 1</td>
<td>2.4</td>
<td>7.6</td>
</tr>
<tr>
<td>50%</td>
<td>0.59 to 1</td>
<td>3.8</td>
<td>6.2</td>
</tr>
<tr>
<td>60%</td>
<td>0.99 to 1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>80%</td>
<td>3 to 1</td>
<td>7.4</td>
<td>2.6</td>
</tr>
<tr>
<td>100%</td>
<td>1 to 0</td>
<td>10</td>
<td>0.0</td>
</tr>
</tbody>
</table>

### Appendix 2: Location of care considerations

- Critical care (CC) level care is best delivered in a critical care unit (CCU) but this needs to be balanced against the practicalities of moving equipment (see below), familiarity of staff with equipment and the impact on staffing ratios.
• It is likely that care will need to be provided in other ‘surge’ areas of the hospital.

• **Anaesthetic machines on CCU:**
  – Sources of piped oxygen and air will be required.
  – **Scavenging is not required** if viral filters are placed in the circuit and inhaled anaesthetic agents are not being used.
  – **Suction outlets cannot be attached to the WAGD connection** on the machine due to connector incompatibility.

• **Theatre:**
  – **Potentially an isolated location** so systems to call for assistance will be required.
  – Clearly marked emergency alarm.
  – Alarms should set to **maximum volume**.
  – Staffing ratios and skill mix will be partly determined by the **local geography**

• **Recovery/PACU/Ward:**
  – Physical space, suction and sources of piped oxygen and air are the minimum requirements.
  – **Potentially an isolated location** so systems to call for assistance will be required.
  – Staffing ratios and skill mix will need to take into account the **local geography**.
  – Typically, open locations with the potential to spread infectious agents and increased noise levels.

**Appendix 3: Staffing considerations**

• **An operating department practitioner/anaesthetic nurse** should be immediately available to help with set up, testing, troubleshooting and turnaround of the machine.

• **Medical staff trained to use these devices** should also be immediately available.

• Staff mix/deployment should take into account both clinical skills and competency of staff to the use equipment in that area.

• A **teamwork approach** will be required – see the [critical care staffing framework](#).
Appendix 4: Self-test check list

You will need:

• ETT clamp or similar.
• Disposables that need to be exchanged.
• Alternative means of ventilation: transport ventilator (with appropriate circuit and filters) or self-inflating bag with PEEP.
• Someone competent to perform anaesthetic machine self-test.
• Someone competent to manage the ventilation of the patient while they are disconnected from the anaesthetic machine.
• Drugs: neuromuscular blocker and sedation (both optional).

Checklist:

✓ To prevent coughing consider the need for neuromuscular blockade.
✓ Prepare alternative means of ventilation.
✓ Note current ventilation +/- alarm settings (so that they can be reprogrammed)
  o Mode of ventilation
  o Tidal volume and respiratory rate
  o I:E ratio
  o PEEP
  o Fresh gas flow
  o \(\text{FiO}_2\) and ETCO\(_2\) and other alarms that are being monitored by the machine.
✓ Open the anaesthetic machine APL valve and turn off fresh gas flows.
✓ Clamp the ETT at the end of the inspiratory phase (to maintain lung volume).
✓ Switch the anaesthetic machine to manual ventilation mode.
✓ Disconnect the ETT from the breathing circuit and HME/filter.
✓ Connect the patient to the alternative means of ventilation.
✓ Unclamp the ETT and begin ventilating the patient.
✓ Replace any disposables that need to be exchanged.
✓ Power down the anaesthetic machine, restart, and perform self-test.
✓ Once the self-test is complete, re-programme the machine using the values noted.
✓ Ensure the anaesthetic machine is in manual ventilation mode.
✓ Clamp the ETT at the end of the inspiratory phase (to maintain lung volume).
✓ Stop ventilation with the alternative means of ventilation.
✓ Disconnect the ETT from the alternative means of ventilation.
✓ Connect the ETT to the anaesthetic machine.
✓ Unclamp the ETT.
✓ Switch the anaesthetic machine to the pre-programmed ventilator mode.
✓ Confirm appropriate ventilation.
## Appendix 5: Additional monitoring schedule

<table>
<thead>
<tr>
<th>Task</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Continuous</td>
</tr>
<tr>
<td></td>
<td>Hourly</td>
</tr>
<tr>
<td></td>
<td>4 hours</td>
</tr>
<tr>
<td></td>
<td>12 hours</td>
</tr>
<tr>
<td></td>
<td>24 hours</td>
</tr>
<tr>
<td></td>
<td>72 hours</td>
</tr>
<tr>
<td>Alarms</td>
<td>X</td>
</tr>
<tr>
<td>Check CO₂ absorber - change if rising inspired CO₂ or less than 1/3 colour unchanged</td>
<td>X</td>
</tr>
<tr>
<td>Monitored parameters</td>
<td>X</td>
</tr>
<tr>
<td>- inspired oxygen</td>
<td></td>
</tr>
<tr>
<td>- inspired and expired CO₂</td>
<td></td>
</tr>
<tr>
<td>- inspired and expired inhalational agent (if using)</td>
<td></td>
</tr>
<tr>
<td>Inspect circuit and water traps for accumulation of water</td>
<td>X</td>
</tr>
<tr>
<td>Check vaporiser fill level (if using for sedation)</td>
<td>X</td>
</tr>
<tr>
<td>Increase fresh gas flow to aid drying of circuit</td>
<td>X</td>
</tr>
<tr>
<td>Consider filter/HME(F) replacement*</td>
<td>X*</td>
</tr>
<tr>
<td>Perform self-test**/***</td>
<td>X**</td>
</tr>
<tr>
<td></td>
<td>X***</td>
</tr>
</tbody>
</table>

*Replacement interval may be determined by performance and availability from supplier.

**Manufactures recommend interval.

***Manufactures recommend interval during pandemic.
Appendix 6: Cleaning and decontamination between patients

- **Cycle the power** (turn on/off) before preparing for a new patient.
- **Perform a complete system self-test**, not just a leak test.
- **There should be no risk of contamination of the machine** if appropriate filter configuration has been used.
- **If there are concerns about contamination** of the machine, then follow the manufactures decontamination advice.
- **Discard disposable items** – breathing circuit, reservoir bag, patient masks, gas sampling tubing and filters.
- **Wipe all exposed services.**
- Links to manufacture’s cleaning instructions are available on the Anesthesia Patient Safety Foundation website.

Appendix 7: Oxygen - consumption/conservation

- The **requirement** to conserve oxygen will depend on local infrastructure and patient demand.
- **Pneumatically powered ventilators consume more oxygen** than electrically powered ones (in general).
- **Electrically powered ventilators do not consume oxygen** to develop pressure and flow (currently only made by Draeger).
- **Most bellows-type ventilators use oxygen** as the drive gas
  - Consumed at approximately the minute ventilation (considerably more than fresh gas oxygen consumption).
  - **The drive gas can be modified to use compressed air**, by a clinical engineer
    - recalibrating the system using software changes
    - plan machine conversions as not all theatres have pipeline 4bar air supplies and will need cylinders if used
    - often need mini Schrader connectors not held by EBME
    - produces a 10% error in tidal volume
- **Oxygen generators cannot be used** as the primary oxygen supply as this will likely cause low pressure and low flow.
- **If you use low fresh gas flow to conserve oxygen**, the following requirements must be considered:
  - A good supply of CO₂ absorber material (for example, soda lime.)
  - Medical professionals competent in its use.
  - An appropriate minimum FiO₂ alarm – set relative to the intended FiO₂.
- An FiCO₂ alarm value to be set.
- An increase in the fresh gas flow every four hours to help dry the internal components of the machine.
- Regular inspection of the circuit for accumulation of water or collapse of the reservoir bag/bellows

### Pitfalls
- Rebreathing of CO₂ resulting in raised PaCO₂ and respiratory acidosis.
- Increase resistance in / blockage of circuit due to water accumulation.
- High utilization of CO₂ absorbers.
- Low resilience to leakage of gas from the circuit.

## Appendix 8: Reporting adverse incidents

Any adverse incidents should be reported to spread learning from events across the healthcare system and to help prevent future incidents.

1. Through local reporting systems.

2. National reporting systems:
   - England: [https://yellowcard.mhra.gov.uk/](https://yellowcard.mhra.gov.uk/)
   - Wales: [https://yellowcard.mhra.gov.uk/devices/?type=hcp](https://yellowcard.mhra.gov.uk/devices/?type=hcp)

3. Direct to manufacturers if your local or national systems do not report to them.