Neonatal Ventilation: How to do it?

Please refer to the longer version of this guideline (available on the network website) for further detailed information. Common reasons for neonatal ventilation include either one or a combination of the following:

1. Parenchymal lung disease or VQ mismatch (e.g. RDS, Meconium aspiration, pneumonia, PPHN etc)
2. Poor respiratory drive (e.g. apnoea of prematurity, hypoxic–ischemic encephalopathy, sepsis etc)
3. Lung malformations (e.g. diaphragmatic hernia, CCAM)
4. Mechanical (e.g. abdominal distension, airway obstruction)

General Principles of Conventional Ventilation:

- In neonates, uncuffed ET tube is used, so effective ventilation requires an appropriate sized ET tube inserted to an optimum length. This aims to minimise leak and balance the risk of pressure necrosis. Please see Appendix 1 for ETT length.
- Ventilation is most effective when the lung is ventilated around the Functional Residual Capacity (FRC); when the inward recoil of the lung matches the outward recoil of the chest wall thereby reducing work of breathing and facilitating gas exchange. This equates to lung expansion around the 8-9th posterior ribs on CXR.
- Babies less than 30 weeks gestation; start Caffeine as soon as possible after delivery to aid early extubation.
- Delay or avoid routine opiates if infant likely to be extubated soon.
- Weaning from ventilation and extubation should be achieved at the earliest opportunity (Please see Appendix 2)

Determinants of gas exchange:

Oxygenation:
This is directly related to Mean Airway Pressure (MAP) and FiO2

MAP is affected by –

- Peak Inspiratory pressure (PIP) – Higher the PIP, higher the MAP and better oxygenation
- Positive End Expiratory Pressure (PEEP) – Increasing PEEP will improve oxygenation by recruiting more alveoli provided there is no hyperinflation.
- Inspiratory time (TI) – Longer the TI, higher the MAP and better oxygenation, provided it does not cause hyperinflation.
- Flow – Higher flow improves MAP and oxygenation by reaching PIP quicker. Inappropriately high flow can cause lung injury and increased airway resistance.
- Inadequate flow may not allow adequate PIP to be achieved within the set inspiratory time and increases patient discomfort through flow hunger.

The lung volume generated by MAP is in turn dependent on -

Lung compliance (a measure of stiffness to expansion) - affected by disease; in RDS improved following surfactant.
Lung resistance (a measure of obstruction to airflow) - affected by size and length of ETT, secretions and calibre and spasm of small airways. Ventilate using the biggest size ETT tube that will not cause trauma or pressure necrosis.
Minimise dead space by shortening the length of extra-oral segment of ETT.

CO₂ elimination:
- This is determined by minute ventilation (MV) = Tidal volume × Respiratory rate. The higher the MV (faster RR) the greater the CO₂ elimination.
- Delta P i.e. (PIP-PEEP). A larger Delta P leads to greater CO₂ elimination. Inspiratory time (TI), compliance and resistance all contribute to the Tidal Volume (TV).

Target values for Oxygen Saturations and blood gases:

<table>
<thead>
<tr>
<th>Target values</th>
<th>Oxygen saturations</th>
<th>pH</th>
<th>pCO₂ (kpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preterm infant, first week of life</td>
<td>91-94%</td>
<td>&gt;7.25</td>
<td>4.5 - 8</td>
</tr>
<tr>
<td>Preterm infant after first week of life</td>
<td>91-94%</td>
<td>&gt;7.25</td>
<td>&gt;4.5, allow for compensated permissive hypercapnia</td>
</tr>
<tr>
<td>Term infant at risk of PPHN</td>
<td>&gt;95%</td>
<td>7.3-7.4</td>
<td>4.5 - 6</td>
</tr>
</tbody>
</table>

Target TV – Normally 4-6 mls/Kg for a small baby and up to 8mls/Kg for bigger term/near term babies.
Target MV – 200-300mls/Kg

Aim to always minimise ventilation induced lung injury, avoid both high and suboptimal lung volumes. Always wean the most harmful parameter first

When blood gases are outside desired target ranges check the following:
Wales Neonatal Network Guideline

Reliability of blood gas:
- Did sample contain an air bubble? Was it obtained from a poorly perfused site?
- Has there been a sudden unexpected change from previous blood gas values?

Clinical Condition:
- Is baby’s chest moving adequately? How is the air entry?

Ventilator and tubing:
- Is there an air leak (consider transillumination to exclude a pneumothorax)?
- Are the measured ventilatory values markedly different to the set ones? Is there a large (>40%) endotracheal tube (ETT) leak?

For causes of acute deterioration on a ventilator,
Remember DOPE: Displacement, Obstruction, Pneumothorax, Equipment failure.

Common Scenarios:

Low oxygenation and high CO₂ – (Inadequate lung volume is most likely - Low MAP, TV and MV)
- Clinically evaluate to rule out conditions such as pneumothorax and blocked ETT / displacement.
- In some cases such as early RDS – improving lung compliance by giving surfactant may be the most appropriate solution. Pressure –volume loops or CXR appearance may be helpful.
- Consider changes that affect both MAP and TV:
  o Increase PIP to improve MAP and Delta P. If TV measurements available adjust pressure settings manually to achieve a TV of at least 4mls/Kg and if already achieved consider increasing up to 6mls/Kg.
  o If lungs show signs of atelectasis or consolidation, increasing PEEP is appropriate but ensure that Delta P i.e. (PIP-PEEP) is not reduced. Consult with seniors if PEEP exceeds 6 cm
- Increase FiO₂ and rate as appropriate (enough to achieve target MV) after ensuring that adequate lung expansion and TV is achieved.
- Consider HFOV if poor response or settings considered too aggressive.

Low oxygenation and Low/Normal CO₂ – (Normal MV, possibly normal TV, VQ mismatch – poor diffusion across lung)
- Increase FiO₂ but investigate cause? Pneumonia / PPHN /worsening RDS. Note TV.
- If increments in FiO₂ too big consider increasing MAP without significantly altering TV. Consider:
  o 1st choice - Increase both PIP and PEEP to keep Delta P same — will not work if bigger increments required i.e. >1-2 cm - caution not to overinflate.
  o 2nd choice - Increase I time (TI) to improve time for gas exchange but ensure that I:E ratio is not inverted as this will cause air trapping.
- Adjust rate to modify Minute ventilation.
- If settings too aggressive or poor response consider HFOV / Nitric oxide as appropriate.

Normal /High oxygenation and Low CO₂ – (Over-ventilated - likely high MAP, TV and MV)
- Reduce pressures – PIP as first choice. Try not to reduce PIP to levels that gives a TV < less than 4 mls /Kg. Use VG mode if available with TV@4mls/Kg if high tidal volume noted
- Consider reducing PEEP if lungs are overinflated, reduce FiO₂ as appropriate.
- Consider reducing rate if MV still remains high or if not available if pCO₂ still low. This will not work in SIPPV/PSV if breathing above back up rate – consider autocycling.

Normal /High oxygenation but high CO₂ – (Likely low MV but normal MAP and TV)
- Rule out partial ETT block or secretions – See resistance indices or flow –volume loops if available.
- If possible increase respiratory rate to achieve desired MV. However, beware that increasing rate too much (usually when >60/min and Ti ~0.4sec) may reverse I:E ratio and cause CO₂ retention. Hence, consider reducing Ti simultaneously if > 0.3 seconds.
- Consider reducing PEEP if lungs well inflated (this will reduce MAP but improve Delta P). Do not go below 3 cm as it may cause atelectasis.

References:

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