Deep anesthesia causes poor perfusion, hypoxia and hypoventilation which can result in death. Anesthetic depth is difficult to assess based on physical signs. Heart and respiratory rate changes don’t correlate with changes in Anesthetic depth, although monitoring respiratory rate is important because apnoea can lead to hypoxia. Better indicators are cardiac function (blood flow or pressure) and respiratory function (CO2 clearance) which are depressed a dose-dependently.

Adequacy of ventilation depends on the respiratory rate AND depth (tidal volume) which determine minute ventilation and therefore arterial CO2. Normal minute ventilation (about 200 ml/kg/min for dogs and cats) in conscious animals with normal lungs results in an arterial and therefore alveolar CO2 partial pressure of 35 to 45 mm Hg.

Ventilatory function (minute ventilation) decreases and therefore CO2 increases in a dose-dependent fashion with increasing Anesthetic depth.

End Tidal CO2 monitors measure the CO2 partial pressure using proportional absorption of infrared light. The monitors continuously sample gas at the endotracheal tube connector. The CO2 concentration can be measured directly via a sensor in-line, called mainstream sampling, as shown below.

Alternatively the gas sample may be continuously drawn via a long sample line (sidestream sampling) up to the monitor where the CO2 concentration is measured.

ETCO2 pitfalls and interpretation

A continuous CO2 wave form can be generated which will demonstrate the three phases of expiration during each respiratory cycle.

A = dead space gas, no CO2
B = mixed gas, rising CO2
C = alveolar gas, CO2 plateau
D = inspiration no CO2
E = expiratory plateau

The monitor will continuously read the CO2 level (in % or mm Hg) and display the peak CO2 value (ETCO2) and respiratory rate.

The plateau observed at the end of the CO2 expiratory waveform (phase “C”) ensures that the peak ETCO2 value is determined from an alveolar gas sample. Small tidal volumes, such as with cats, may not allow adequate sampling resulting in waveforms without an “alveolar gas plateau” such as below.

In this case the ETCO2 may be underestimating the true alveolar and arterial CO2.

Cardiac Oscillations

During expiration in animals with large chests, heart beats can force small puffs of gas up the trachea causing “bumps” in phase “C” of the ETCO2 waveform. The monitor will read each “bump” as a new breath, so give erroneous respiratory rate and variable ETCO2 values. The highest CO2 level is in the arterial blood so when cardiac oscillations are present, observe the waveform and note the highest ETCO2 reading which will be closest to the arterial CO2.

Cardiac oscillations such as observed in animals at light planes of anesthesia, will cause similar problems due to variations in the waveform.

Lung disease or atelectasis such as seen during thoracotomies cause an increase in “dead space” ventilation, which dilutes the alveolar gas CO2 concentration resulting in erroneously low ETCO2 estimations. ETCO2 values measured during a thoracotomy should be regarded as erroneous unless there is an arterial blood gas measurement to prove correlation. This dead space error also occurs in anesthetized horses where ETCO2 values can underestimate arterial CO2 by more than 15 mm Hg.

No ETCO2 reading can be due to:
- Failed intubation
- Disconnection between the ET tube and Y piece/ETCO2 sampling point
- Airway occlusion
- Lack of pulmonary blood flow (e.g. cardiac arrest, pulmonary air embolism)

Low ETCO2 can be due to:
- Light anesthesia and pain which increases spontaneous ventilation
- Excessive mechanical ventilation
- Small tidal volume causing a sampling error (e.g. cats)
- Increasing dead space such as cause by alveolar collapse during a thoracotomy

High ETCO2 can be due to:
- Deep anesthesia
- Increased dead space (e.g. long ET tubes)
- Inadequate removal of CO2 by exhausted soda-lime
- Low fresh gas flows in non-rebreathing circuits
- Rebreathing expired gas such as caused by defective 1-way valves

High CO2 causes high HR, BP and injected mucous membranes

<table>
<thead>
<tr>
<th>ETCO2 Values, mm Hg</th>
<th>Anesthesia, Spontaneous Ventilation</th>
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<tbody>
<tr>
<td></td>
<td>Conscious Light GA Deep GA</td>
</tr>
<tr>
<td>Dog</td>
<td>35 - 45</td>
</tr>
<tr>
<td>Cat</td>
<td>30 - 38</td>
</tr>
<tr>
<td>Foal 2 mo.</td>
<td>35 - 45</td>
</tr>
<tr>
<td>Horse</td>
<td>35 - 45</td>
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</tbody>
</table>

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